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Louwet et al.

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Application No. 10/645,160

Examiner: Unassigned

Filed: August 21, 2003

For: **PROCESS FOR PREPARING A SUBSTANTIALLY  
TRANSPARENT CONDUCTIVE LAYER CONFIGURATION**

**CLAIM OF PRIORITY**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

In accordance with the provisions of 35 USC 119, Applicants claim the priority of the following application:

Application No. PCT/EP02/09429, filed in Europe on August 22,  
2002.

A certified copy of the above-listed priority document is enclosed.

Respectfully submitted,

Christopher T. Griffith, Reg. No. 33,392  
LEYDIG, VOIT & MAYER, LTD.  
Two Prudential Plaza, Suite 4900  
180 North Stearns  
Chicago, Illinois 60601-6780  
Telephone: (312) 616-5600  
Facsimile: (312) 616-5700

Date: September 5, 2003

**CERTIFICATE OF MAILING**

I hereby certify that this CLAIM OF PRIORITY (along with any documents referred to as being attached or enclosed) is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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9/5/03



**Bescheinigung**

**Certificate**

**Attestation**

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten internationalen Patentanmeldung überein.

The attached documents are exact copies of the international patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet international spécifiée à la page suivante.

Den Haag, den  
The Hague,  
La Haye, le

13. 08. 2003

Der Präsident des Europäischen Patentamts  
Im Auftrag  
For the President of the European Patent Office  
Le Président de l'Office européen des brevets  
p. o.

H.A.M.W. ter Haar

Patentanmeldung Nr.  
Patent application n°  
Demande de brevet n°

PCT/EP 02/09429

**Blatt 2 der Bescheinigung**  
**Sheet 2 of the certificate**  
**Page 2 de l'attestation**



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Application no.:  
Demande n°:

Anmelder: 1. AGFA-GEVAERT - Mortsel, Belgium (US only)  
Applicant(s): 2. ANDRIESSEN, Hieronymus - Mortsel, Belgium (US only)  
Demandeur(s): 3. CLOOTS, Tom - Mortsel, Belgium (US only)

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4. LOUWET, Frank - Mortsel, Belgium (US only)

## PCT REQUEST

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<b>V</b>	<b>Designation of States</b>	
<b>V-1</b>	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	<p>AP: GH GM KE LS MW MZ SD SL SZ TZ UG ZM ZW and any other State which is a Contracting State of the Harare Protocol and of the PCT</p> <p>EA: AM AZ BY KG KZ MD RU TJ TM and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT</p> <p>EP: AT BE BG CH&amp;LI CY CZ DE DK EE ES FI FR GB GR IE IT LU MC NL PT SE SK TR and any other State which is a Contracting State of the European Patent Convention and of the PCT</p> <p>OA: BF BJ CF CG CI CM GA GN GQ GW ML MR NE SN TD TG and any other State which is a member State of OAPI and a Contracting State of the PCT</p>
<b>V-2</b>	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	<p>AE AG AL AM AT AU AZ BA BB BG BR BY BZ CA CH&amp;LI CN CO CR CU CZ DE DK DM DZ EC EE ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NO NZ OM PH PL PT RO RU SD SE SG SI SK SL TJ TM TN TR TT TZ UA UG US UZ VC VN YU ZA ZM ZW</p>
<b>V-5</b>	<b>Precautionary Designation Statement</b>  In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
<b>V-6</b>	<b>Exclusion(s) from precautionary designations</b>	NONE
<b>VI</b>	<b>Priority claim</b>	NONE
<b>VII-1</b>	<b>International Searching Authority Chosen</b>	European Patent Office (EPO) (ISA/EP)

# PROCESS FOR PREPARING A SUBSTANTIALLY TRANSPARENT CONDUCTIVE LAYER CONFIGURATION

## Field of the invention

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The present invention relates to a process for producing a substantially transparent conductive layer configuration.

## Background of the invention.

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In many applications there is a requirement for inexpensive transparent conducting layers, but a busbar will be also required for some of the (large area) applications. Highly conductive (non-transparent) patterns can be made by screen-printing conducting  
15 pastes such as silver or carbon black pastes. Vacuum evaporation of metals through shadow masks is another method. Yet another method makes use of homogeneous conductive metallized surfaces which can be patterned by use of photoresist technology in combination with a metal etching agent. Photographic films can, under certain  
20 conditions, be used for making electrically conductive silver "images".

US 3,664,837 describes the use of light sensitive evaporated silver halide film which upon exposure and after development results in conductive images. DE 1,938,373 describes a photographic  
25 method for producing conducting paths, resistances and capacitors for microcircuits starting from coated silver halide emulsions. US 3,600,185 describes the production of electrically conductive patterns by means of diffusion transfer techniques.

Combinations of a transparent polymer-based conductor and a  
30 high conductive (non-transparent) pattern are described in some publications. DE-A 196 27 071 discloses an electroluminescent configuration, which contains hole and/or electron injecting layers, wherein the polymeric organic conductor is selected from the group of polyfurans, polypyrroles, polyanilines, polythiophenes  
35 and polypyridines. DE-A 196 27 071 also discloses the use of poly(3,4-ethylenedioxythiophene) as a charge-injection layer on transparent metallic electrodes such as ITO (indium-tin oxide) and that the following materials are suitable as transparent and conductive materials: a) metal oxides e.g. ITO, tin oxide etc.; b)  
40 semi-transparent metal films e.g. Au, Pt, Ag, Cu etc. The latter being applied by vacuum techniques.

EP-A 510 541 discloses an organic electroluminescent device having an anode, an organic hole injection transport layer, an organic luminescent layer and a cathode formed sequentially in this order, wherein the organic hole injection transport layer contains  
5 a metal complex and/or a metal salt of an aromatic carboxylic acid. EP-A 510 541 further discloses that the conductive layers used in such devices may have a multi-layer structure by depositing different types of conductive materials selected from a metal, e.g. Al, Au, Ag, Ni, Pd or Te, a metal oxide, carbon black or a  
10 conductive resin such as poly(3-methylthiophene), but no specific combinations are exemplified.

US 5,447,824 discloses a method of manufacturing a pattern of an electrically conductive polymer on a substrate surface, said method comprising: a) forming a liquid layer on a surface of said  
15 substrate from a solution containing a material capable of forming said electrically conductive polymer upon being heated, e.g. 3,4-ethylenedioxythiophene, an oxidizing agent and a base, b) exposing said liquid layer to patterned radiation, and c) heating said layer thereby forming a pattern of an electrically conductive polymer,  
20 said conductive polymer being formed in unexposed areas and a non-conductive polymer being formed in the exposed areas of the layer. The galvanic provision of the conductive polymer pattern with a metal layer, e.g. silver, copper, nickel or chromium, is also disclosed in US 5,447,824.

25 WO 98/54767 discloses a conductive layer system, particularly for a transparent or semi-transparent electrode or electroluminescent configuration, comprising at least two layers, characterized in that the first layer contains an organic or organometallic electrically conductive polymer, which is  
30 transparent or semi-transparent in the visible range of the electromagnetic spectrum, e.g. a polymer selected from the group consisting of polythiophene, polypyrrole, polyaniline, polyacetylene or their optionally substituted derivatives and the second layer contains at least one electrically conductive  
35 inorganic compound or a metal or an appropriately doped semi-metal e.g. a material selected from the group consisting of Cu, Ag, Au, Pt, Pd, Fe, Cr, Sn, Al or their alloys or conductive carbon. In a preferred embodiment the second layer is a conductive pattern formed by an open grid structure, preferably with a 5-500  $\mu\text{m}$  grid  
40 so that it cannot be perceived by the human eye. Invention example 2 discloses a poly(3,4-ethylenedioxythiophene) [PEDOT]/poly(styrene sulphonate) [PSS] layer with a surface resistivity of 1500  $\Omega/\text{square}$

to which conducting tracks of Leitsilber (a silver particle dispersion) ca. 2 mm wide had been applied by a printing technique.

The layer configuration disclosed in Example 2 of WO 98/54767 has the disadvantages of the grid of Leitsilber requiring a  
5 thickness of 5 to 10  $\mu\text{m}$  to realize layers with a surface resistance of 0.5 to 1  $\Omega/\text{square}$ , which means that the surface of the configuration will have a certain roughness which will limit its applications, making it difficult to apply a thin, e.g. 100 nm, functional layer. Furthermore, an aqueous PEDOT/PSS dispersion  
10 would not wet such a Leitsilber grid and hence a usable multilayer conductive configuration would not result.

Furthermore, such a reversed order: first a conductive metal grid and then a conductive transparent polymeric layer will certainly be of more importance in LED devices and thin film  
15 photovoltaic devices, in which the transparent polymeric electrode performs as a hole-injecting layer.

Aspects of the invention.

20 It is therefore an aspect of the present invention to provide a process for preparing a multilayer electrode configuration comprising a conductive polymer layer and a conductive metal layer in which it is possible to realize either the conductive polymer layer or the conductive metal layer nearer the support.

25 It is a further aspect of the present invention to provide a process for preparing a multilayer electrode configuration comprising a conductive polymer layer and a conductive metal layer in which it is possible to apply a functional layer system.

It is also an aspect of the present invention to prevent ion  
30 migration from the conductive electrode.

Further aspects and advantages of the invention will become apparent from the description hereinafter.

Summary of the invention.

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It has been surprisingly found that by preparing the silver grid in a multilayer configuration comprising a first layer containing an intrinsically conductive polymer, such as PEDOT/PSS, and a second layer which is a silver pattern using a photographic  
40 process enables a configuration to be realized with the PEDOT/PSS layer or the silver pattern outermost such that functional layers can be readily applied to its outermost layer.

Aspects of the present invention are realized by a process for preparing a substantially transparent conductive layer configuration on a support, the layer configuration comprising in any order at least a first layer containing an intrinsically  
5 conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, the process comprising the step of: preparing the second layer by a photographic process.

Aspects of the present invention are also realized by a layer configuration obtainable by the process, according to the present  
10 invention, wherein the layer configuration further contains a 1-phenyl-5-mercapto-tetrazole compound in which the phenyl group is substituted with at least one electron accepting group.

Aspects of the present invention are also realized by a light emitting diode comprising a layer configuration prepared according  
15 to the above-mentioned process.

Aspects of the present invention are also realized by a photovoltaic device comprising a layer configuration prepared according to the above-mentioned process.

Aspects of the present invention are also realized by a  
20 transistor comprising a layer configuration prepared according to the above-mentioned process.

Aspects of the present invention are also realized by an electroluminescent device comprising a layer configuration prepared according to the above-mentioned process.

25 Preferred embodiments are disclosed in the dependent claims.

Detailed description of the invention.

Figure 1 shows four silver patterns, pattern (a) representing a  
30 continuous silver layer  $3 \times 3 \text{ cm}^2$  in area, pattern (b) representing a regular strip pattern, the parallel strips being 10 mm apart and having a width of 1 mm; pattern (c) representing a regular strip pattern, the parallel strips being 5 mm apart and having a width of 150  $\mu\text{m}$ ; and pattern (d) representing no silver development.

35 Figure 2 shows side (upper) and top (lower) views of a sequential process for building up a module with a separate photovoltaic cell, two serially connected photovoltaic cells and three serially connected photovoltaic cells using a six step process in which: A =  
40 a subbed support; B = a gelatin layer; C = a palladium sulphide nucleation layer; D = a conductive silver pattern; E = a highly conductive PEDOT/PSS-layer; F = a shunt resistance hindering layer;



G = a photovoltaic blend; and H = a lithium fluoride/aluminium electrode. In step 1 in which the subbed surface of a subbed poly(ethylene terephthalate) film A [the subbing layer represented by hatching] is coated with a gelatin layer B; step 2 in which a  
5 palladium sulfide nucleation layer C is applied to the gelatin layer B; step 3 in which a diffusion transfer process is carried out in which a conductive silver pattern D is produced; step 4 in which the conductive silver pattern D is coated with a highly conductive PEDOT/PSS-layer E by e.g. screen printing, and  
10 optionally additionally with a shunt resistance hindering layer F, e.g. a PEDOT/PSS layer or a PEDOT-S/polycationic or polyanionic polymer with a higher surface resistance; step 5 in which layer E or F is coated with a photovoltaic blend, e.g. a blend of MDMO-PPV/PCBM G, by e.g. curtain coating, spincoating or screen  
15 printing; and step 6 in which layer G is coated with a non-continuous lithium fluoride/aluminium layer forming a top electrode H.

#### Definitions

20

The term alkyl means all variants possible for each number of carbon atoms in the alkyl group i.e. for three carbon atoms: n-propyl and isopropyl; for four carbon atoms: n-butyl, isobutyl and tertiary-butyl; for five carbon atoms: n-pentyl, 1,1-dimethyl-  
25 propyl, 2,2-dimethylpropyl and 2-methyl-butyl etc.

The term aqueous for the purposes of the present invention means containing at least 60% by volume of water, preferably at least 80% by volume of water, and optionally containing water-miscible organic solvents such as alcohols e.g. methanol, ethanol,  
30 2-propanol, butanol, iso-amyl alcohol, octanol, cetyl alcohol etc.; glycols e.g. ethylene glycol; glycerine; N-methyl pyrrolidone; methoxypropanol; and ketones e.g. 2-propanone and 2-butanone etc.

The term "support" means a "self-supporting material" so as to distinguish it from a "layer" which may be coated on a support, but  
35 which is itself not self-supporting. It also includes any treatment necessary for, or layer applied to aid, adhesion to the support.

The term continuous layer refers to a layer in a single plane covering the whole area of the support and not necessarily in  
40 direct contact with the support.

The term coating is used as a generic term including all means of applying a layer including all techniques for producing continuous layers, such as curtain coating, doctor-blade coating etc., and all techniques for producing non-continuous layers such as screen printing, ink jet printing, flexographic printing, and techniques for producing continuous layers

The term intrinsically conductive polymer means organic polymers which have (poly)-conjugated  $\pi$ -electron systems (e.g. double bonds, aromatic or heteroaromatic rings or triple bonds) and whose conductive properties are not influenced by environmental factors such as relative humidity.

The term "conductive" is related to the electric resistance of the material. The electric resistance of a layer is generally expressed in terms of surface resistance  $R_s$  (unit  $\Omega$ ; often specified as  $\Omega/\text{square}$ ). Alternatively, the conductivity may be expressed in terms of volume resistivity  $R_v = R_s \cdot d$ , wherein  $d$  is the thickness of the layer, volume conductivity  $k_v = 1/R_v$  [unit: S(iemens)/cm] or surface conductance  $k_s = 1/R_s$  [unit: S(iemens).square].

The term photographic refers to any photochemical process particularly those based on silver halide processes.

The term silver salt diffusion transfer process refers to a process developed independently by A. Rott [GB 614,155 and Sci. Photogr., (2)13, 151 (1942)] and E. Weyde [DE 973,769] and described by G. I. P. Levenson in Chapter 16 of "The Theory of the Photographic Process Fourth Edition", edited by T. H. James, pages 466 to 480, Eastman Kodak Company, Rochester (1977).

The term substantially transparent means that the integral transmission of visible light is above 40% of the incident light normal to the layer configuration of the present invention i.e. the layer had an overall optical density of less than 0.40, although local transmission of visible light through the lines of the silver pattern may be well below 10% of the incident light normal to the layer configuration of the present invention i.e. well above an optical density of 1.0.

The abbreviation PEDOT represents poly(3,4-ethylenedioxythiophene).

The abbreviation PSS represents poly(styrene sulphononic acid) or poly(styrenesulphonate).

The abbreviation PEDOT-S represents poly[4-(2,3-dihydrothieno[3,4-*b*][1,4]dioxin-2-ylmethoxy)-butane-1-sulphonic acid].

## Process for preparing a layer configuration

Aspects of the present invention are realized by a process for preparing a substantially transparent conductive layer

5 configuration on a support, the layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, the process comprising the step of: preparing the second layer by a photographic process.

10 According to a first embodiment of the process, according to the present invention the process further comprises coating the first layer prior to preparing the second layer by a photographic process.

According to a second embodiment of the process, according to 15 the present invention, the photographic process comprises the steps of: coating the support with a layer containing silver halide and gelatin with a weight ratio of gelatin to silver halide in the range of 0.05 to 0.3, image-wise exposing the silver halide-containing layer, and developing the exposed silver halide- 20 containing layer to produce the second layer.

According to a third embodiment of the process, according to the present invention, the process comprises the steps of: coating the support with the first layer, coating the first layer with a layer containing silver halide and gelatin with a weight ratio of 25 gelatin to silver halide in the range of 0.05 to 0.3, image-wise exposing the silver halide-containing layer, and developing the exposed silver halide-containing layer to produce the second layer.

According to a fourth embodiment of the process, according to the present invention, the process comprises the steps of: coating 30 the support a layer containing silver halide and gelatin with a weight ratio of gelatin to silver halide in the range of 0.05 to 0.3, coating the silver halide-containing layer with the first layer, image-wise exposing the silver halide-containing layer, and developing the exposed silver halide-containing layer to produce 35 the second layer.

According to a fifth embodiment of the process, according to the present invention, the process comprises the steps of: coating the support with a layer containing silver halide and gelatin with a weight ratio of gelatin to silver halide in the range of 0.05 to 40 0.3, image-wise exposing the silver halide-containing layer, developing the exposed silver halide-containing layer to produce

the second layer, and coating the second layer with the first layer.

According to a sixth embodiment of the process, according to the present invention, the photographic process comprises the steps  
5 of: coating the support with a non-continuous layer of a nucleation agent; producing the second layer on the non-continuous nucleation layer using silver salt diffusion transfer.

According to a seventh embodiment of the process, according to the present invention, the photographic process comprises the steps  
10 of: coating the support with the first layer, coating the first layer with a layer of a nucleation agent; producing a non-continuous silver layer on the nucleation layer using silver salt diffusion transfer.

According to an eighth embodiment of the process, according to  
15 the present invention, the photographic process comprises the steps of: coating the support with a non-continuous layer of a nucleation agent; coating the non-continuous layer of a nucleation agent with the first layer; and producing a non-continuous silver layer on the non-continuous nucleation layer using silver salt diffusion  
20 transfer.

According to a ninth embodiment of the process, according to the present invention, the photographic process comprises the steps of: coating the support with a non-continuous layer of palladium sulphide, e.g. palladium sulphide nano-particles, as nucleation  
25 agent; producing a non-continuous silver layer on the non-continuous nucleation layer using silver salt diffusion transfer.

According to a tenth embodiment of the process, according to the present invention, the process comprises the steps of: coating the support with a non-continuous layer of a nucleation agent;  
30 producing the second layer on the non-continuous nucleation layer using silver salt diffusion transfer; and coating the second layer with the first layer.

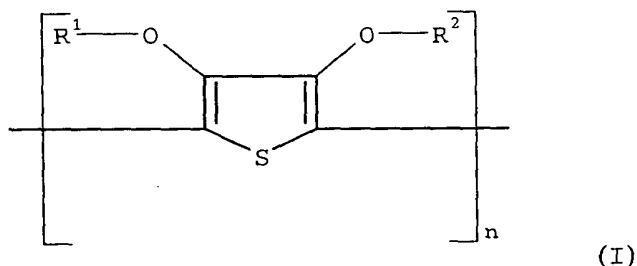
According to an eleventh embodiment of the process, according to the present invention, the first layer is applied by a printing  
35 process.

#### Intrinsically conductive polymer

The intrinsically conductive polymers used in the present  
40 invention can be any intrinsically conductive polymer known in the art e.g. polyacetylene, polypyrrole, polyaniline, polythiophene, etc. Details about suitable intrinsically conductive polymers can

be found in textbooks, such as "Advances in Synthetic Metals", ed. P. Bernier, S. Lefrant, and G. Bidan, Elsevier, 1999; "Intrinsically Conducting Polymers: An Emerging Technology", Kluwer (1993); "Conducting Polymer Fundamentals and Applications, A  
 5 Practical Approach", P. Chandrasekhar, Kluwer, 1999; and "Handbook of Organic Conducting Molecules and Polymers", Ed. Walwa, Vol. 1-4, Marcel Dekker Inc. (1997).

According to a twelfth embodiment of the process, according to the present invention, the intrinsically conductive polymer  
 10 contains structural units represented by formula (I):



in which, each of  $R^1$  and  $R^2$  independently represents hydrogen or a  $C_{1-4}$  alkyl group or together represent an optionally substituted  $C_{1-4}$  alkylene group or a cycloalkylene group.

15 According to a thirteenth embodiment of the process, according to the present invention, the intrinsically conductive polymer is a polymer or copolymer of a 3,4-dialkoxythiophene in which the two alkoxy groups together represent an optionally substituted oxy-alkylene-oxy bridge.

20 According to a fourteenth embodiment of the process, according to the present invention, the intrinsically conductive polymer is a polymer or copolymer of a 3,4-dialkoxy-thiophenes in which the two alkoxy groups together represent an optionally substituted oxy-alkylene-oxy bridge and is selected from the group consisting of:  
 25 poly(3,4-methylenedioxythiophene), poly(3,4-methylenedioxy-thiophene) derivatives, poly(3,4-ethylenedioxythiophene), poly(3,4-ethylene-dioxythiophene) derivatives, poly(3,4-propylenedioxy-thiophene), poly(3,4-propylenedioxy-thiophene) derivatives, poly(3,4-butylenedioxythiophene) and poly(3,4-butylenedioxy-  
 30 thiophene) derivatives and copolymers thereof.

According to a fifteenth embodiment of the process, according to the present invention, the intrinsically conductive polymer is a polymer or copolymer of a 3,4-dialkoxy-thiophenes in which the two alkoxy groups together represent an optionally substituted oxy-  
 35 alkylene-oxy bridge and the substituents for the oxy-alkylene-oxy

bridge are alkyl, alkoxy, alkyloxyalkyl, carboxy, alkylsulfonato and carboxy ester groups.

According to a sixteenth embodiment of the process, according to the present invention, the intrinsically conductive polymer is a polymer or copolymer of a 3,4-dialkoxy-thiophenes in which the two alkoxy groups together represent an optionally substituted oxy-alkylene-oxy bridge and the two alkoxy groups together represent an optionally substituted oxy-alkylene-oxy bridge which is a 1,2-ethylene group, an optionally alkyl-substituted methylene group, an optionally C1-12 alkyl- or phenyl-substituted 1,2-ethylene group, a 1,3-propylene group or a 1,2-cyclohexylene group.

Such polymers are disclosed in Handbook of Oligo- and Polythiophenes Edited by D. Fichou, Wiley-VCH, Weinheim (1999); by L. Groenendaal et al. in Advanced Materials, volume 12, pages 481-494 (2000); L. J. Kloeppner et al. in Polymer Preprints, volume 40(2), page 792 (1999); P. Schottland et al. in Synthetic Metals, volume 101, pages 7-8 (1999); and D. M. Welsh et al. in Polymer Preprints, volume 38(2), page 320 (1997).

Organic polymer containing structural units according to formula (I) can be polymerized chemically or electrochemically. Chemical polymerization can be carried out oxidatively or reductively. The oxidation agents used for the oxidative polymerisation of pyrrole, such as described for example in J. Amer. Chem. Soc., vol. 85, pages 454-458 (1963) and J. Polym. Sci. Part A Polymer Chemistry, vol. 26, pages 1287-1294 (1988), can be utilized for the oxidative polymerization of thiophenes. According to a seventh embodiment of the present invention, the inexpensive and easily accessible oxidation agents such as iron(III) salts such as  $\text{FeCl}_3$ , the iron(III) salts of organic acids, e.g.  $\text{Fe}(\text{OTs})_3$ ,  $\text{H}_2\text{O}_2$ ,  $\text{K}_2\text{Cr}_2\text{O}_7$ , alkali and ammonium persulphates, alkali perborates and potassium permanganate are used in the oxidative polymerization.

Theoretically the oxidative polymerization of thiophenes requires 2.25 equivalents of oxidation agent per mole thiophene of formula (I) [see e.g. J. Polym. Sci. Part A Polym. Chem., vol. 26, pages 1287-1294 (1988)]. In practice an excess of 0.1 to 2 equivalents of oxidation agent is used per polymerizable unit. The use of persulphates and iron(III) salts has the great technical advantage that they do not act corrosively. Furthermore, in the presence of particular additives oxidative polymerization of the thiophene compounds according to formula (I) proceeds so slowly that the thiophenes and oxidation agent can be brought together as a solution or paste and applied to the substrate to be treated.

After application of such solutions or pastes the oxidative polymerization can be accelerated by heating the coated substrate as disclosed in US 6,001,281 and WO 00/14139 herein incorporated by reference.

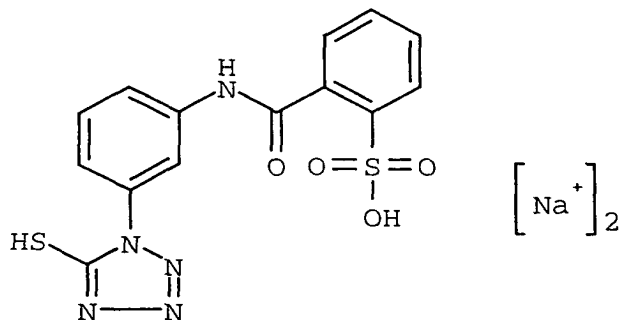
5 Reductive polymerization can be performed using the Stille (organotin) or Suzuki (organoboron) routes described in 2002 by Apperloo et al. in Chem. Eur. Journal, volume 8, pages 2384-2396, and as disclosed in 2001 in Tetrahedron Letters, volume 42, pages 155-157 and in 1998 in Macromolecules, volume 31, pages 2047-2056  
 10 respectively or with nickel complexes as disclosed in 1999 in Bull. Chem. Soc. Japan, volume 72, page 621 and in 1998 in Advanced Materials, volume 10, pages 93-116.

15 1-Phenyl-5-mercapto-tetrazole compound substituted with at least one electron accepting group

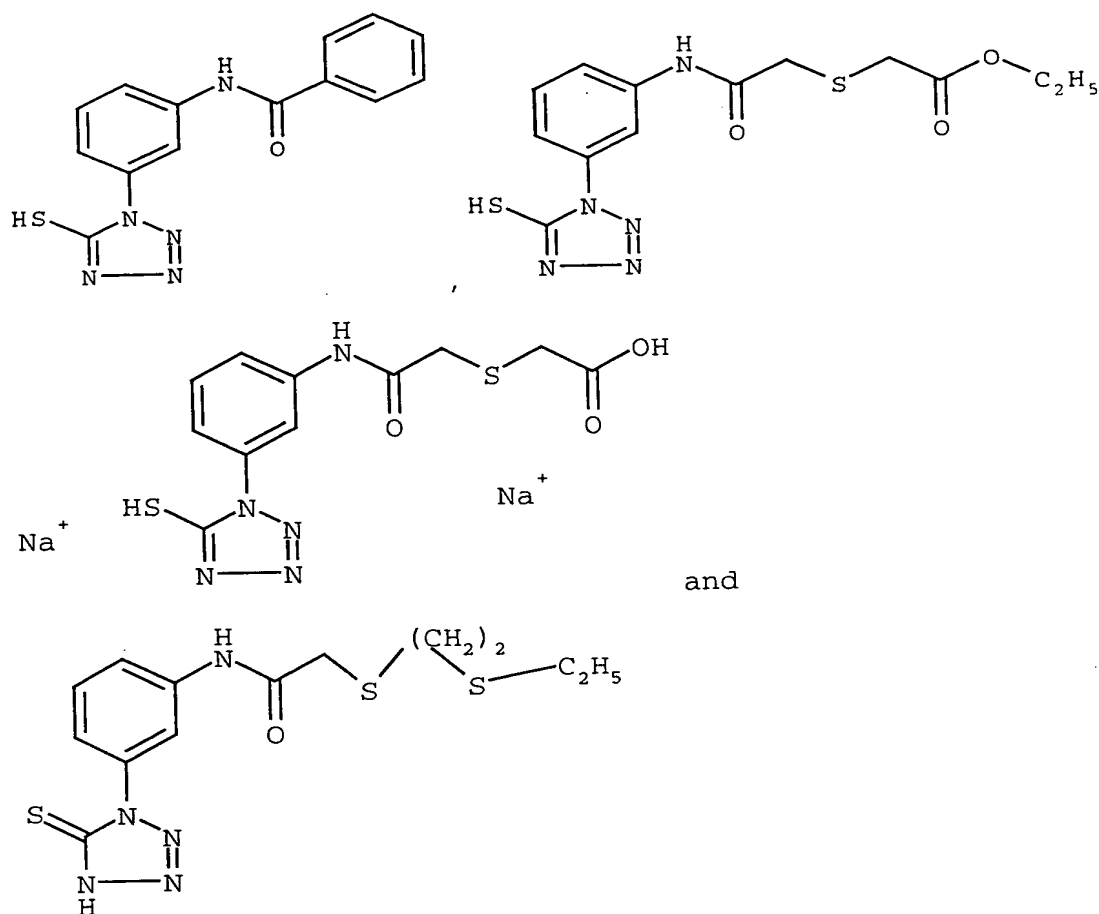
Aspects of the present invention are also realized by a layer configuration obtainable by the process, according to the present invention, wherein the layer configuration further contains a 1-  
 20 phenyl-5-mercapto-tetrazole compound in which the phenyl group is substituted with at least one electron accepting group.

According to a first embodiment of the layer configuration conducting layer obtainable by the process, according to the present invention, the electron accepting group is selected from  
 25 the group consisting of chloride, fluoride, cyano, sulfonyl, nitro, acid amido and acylamino groups.

According to a second embodiment of the layer configuration obtainable by the process, according to the present invention, the 1-phenyl-5-mercapto-tetrazole compound in which the phenyl group is  
 30 substituted with at least one electron accepting group is selected from the group consisting of: 1-(3',4'-dichlorophenyl)-5-mercapto-tetrazole,



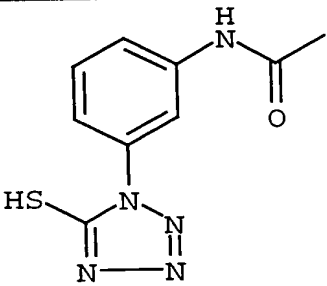
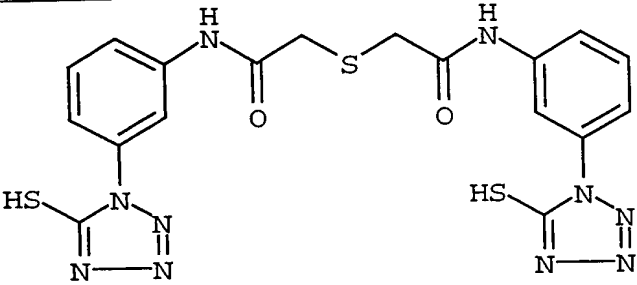
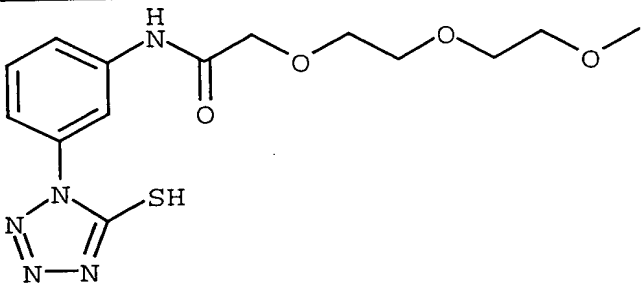
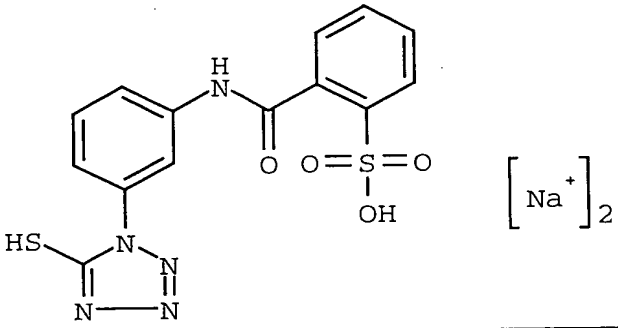
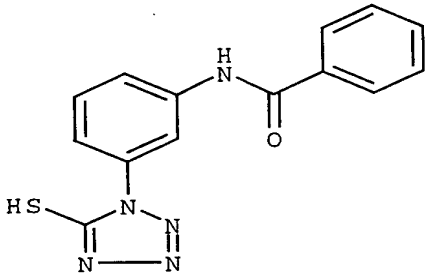
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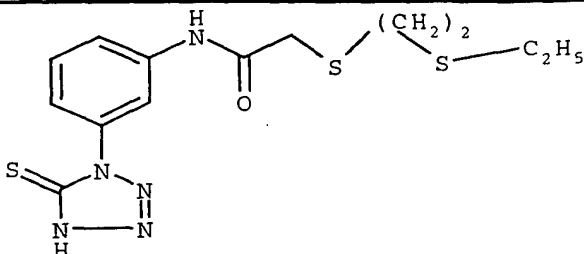
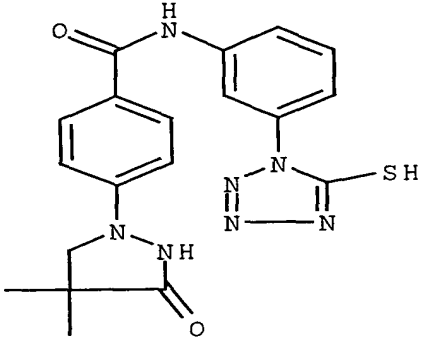
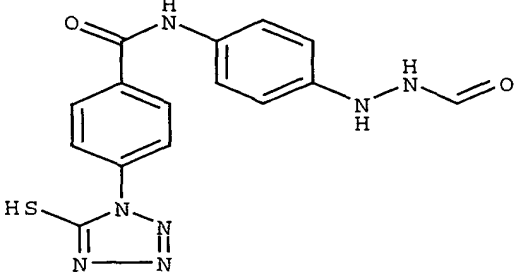
Suitable 1-phenyl-5-mercapto-tetrazole compounds with substituted phenyl groups [PMT], according to the present invention, include:

	Structural formula	
PMT01		1-(3',4'-dichlorophenyl)-5-mercapto-tetrazole



PMT02		1-(3'-acetylamino-phenyl)-5-mercapto-tetrazole
PMT03		
PMT04		
PMT05		
PMT06		1-(3'-benzoylamino-phenyl)-5-mercapto-tetrazole

PMT07	<p>Chemical structures for PMT07: 4-((4-mercapto-1,2,3,4-tetrazol-1-yl)amino)benzoic acid and triethylamine.</p>	
PMT08	<p>Chemical structures for PMT08: 4-((4-mercapto-1,2,3,4-tetrazol-1-yl)amino)benzoic acid ethyl ester and triethylamine.</p>	
PMT09	<p>Chemical structures for PMT09: 4-((4-mercapto-1,2,3,4-tetrazol-1-yl)amino)benzoic acid sodium salt and triethylamine.</p>	
PMT10	<p>Chemical structures for PMT10: 4-((4-mercapto-1,2,3,4-tetrazol-1-yl)amino)benzoic acid and triethylamine.</p>	
PMT11	<p>Chemical structures for PMT11: 4-((4-mercapto-1,2,3,4-tetrazol-1-yl)amino)benzoic acid and triethylamine.</p>	

PMT12		
PMT13		
PMT14		

### Printing inks containing an intrinsically conductive polymer

According to a seventeenth embodiment of the process,  
 5 according to the present invention, the first layer is applied by a printing process using an ink or paste containing an intrinsically conductive polymer.

A printing ink or paste containing between 0.08 and 3.0% by weight of polymer or copolymer of a 3,4-dialkoxythiophene in which  
 10 the two alkoxy groups may be the same or different or together represent an optionally substituted oxy-alkylene-oxy bridge, a polyanion and non-aqueous solvent can be prepared from a dispersion of the polymer or copolymer of (3,4-dialkoxythiophene) and the polyanion in water by a method comprising the steps of: i) mixing  
 15 at least one non-aqueous solvent with the aqueous dispersion of the polymer or copolymer of (3,4-dialkoxythiophene) and the polyanion; and ii) evaporating water from the mixture prepared in step i)

until the content of water therein is reduced by at least 65% by weight.

### Surfactants

5

According to a third embodiment of the layer configuration, according to the present invention, the layer configuration further contains a surfactant.

According to a fourth embodiment of the layer configuration,  
10 according to the present invention, the layer configuration further contains a non-ionic surfactant e.g. ethoxylated/fluoro-alkyl surfactants, polyethoxylated silicone surfactants, polysiloxane/polyether surfactants, ammonium salts of perfluoro-alkylcarboxylic acids, polyethoxylated surfactants and fluorine-  
15 containing surfactants.

Suitable non-ionic surfactants include:

- Surfactant no. 01 = ZONYL™ FSN, a 40% by weight solution of  $F(CF_2CF_2)_{1-9}CH_2CH_2O(CH_2CH_2O)_xH$  in a 50% by weight solution of isopropanol in water where  $x = 0$  to about 25, from DuPont;
- Surfactant no. 02 = ZONYL™ FSN-100:  $F(CF_2CF_2)_{1-9}CH_2CH_2O(CH_2CH_2O)_xH$  where  $x = 0$  to about 25, from DuPont;
- Surfactant no. 03 = ZONYL™ FS300, a 40% by weight aqueous solution of a fluorinated surfactant, from DuPont;
- Surfactant no. 04 = ZONYL™ FSO, a 50% by weight solution of a mixture of ethoxylated non-ionic fluoro-surfactant with the formula:  $F(CF_2CF_2)_{1-7}CH_2CH_2O(CH_2CH_2O)_yH$  where  $y = 0$  to ca. 15 in a 50% by weight solution of ethylene glycol in water, from DuPont;
- Surfactant no. 05 = ZONYL™ FSO-100, a mixture of ethoxylated non-ionic fluoro-surfactant from DuPont with the formula:  $F(CF_2CF_2)_{1-7}CH_2CH_2O(CH_2CH_2O)_yH$  where  $y = 0$  to ca. 15 from DuPont;
- Surfactant no. 06 = Tegoglide™ 410, a polysiloxane-polymer copolymer surfactant, from Goldschmidt;
- Surfactant no. 07 = Tegowet™, a polysiloxane-polyester copolymer surfactant, from Goldschmidt;
- Surfactant no. 08 = FLUORAD™FC431:  $CF_3(CF_2)_7SO_2(C_2H_5)N-CH_2CO-(OCH_2CH_2)_nOH$  from 3M;
- Surfactant no. 09 = FLUORAD™FC126, a mixture of the ammonium salts

of perfluorocarboxylic acids, from 3M;  
 Surfactant no. 10 = Polyoxyethylene-10-lauryl ether  
 Surfactant no. 11 = FLUORAD™FC430, a 98.5% active fluoroaliphatic ester from 3M;

According to a fifth embodiment of the layer configuration, according to the present invention, the layer configuration further contains an anionic surfactant.

5      Suitable anionic surfactants include:

Surfactant no. 12 = ZONYL™ 7950, a fluorinated surfactant, from DuPont;  
 Surfactant no. 13 = ZONYL™ FSA, 25% by weight solution of  $F(CF_2CF_2)_{1-9}CH_2CH_2SCH_2CH_2COOLi$  in a 50% by weight solution of isopropanol in water, from DuPont;  
 Surfactant no. 14 = ZONYL™ FSE, a 14% by weight solution of  $[F(CF_2CF_2)_{1-7}CH_2CH_2O]_xP(O)(ONH_4)_y$  where  $x = 1$  or  $2$ ;  $y = 2$  or  $1$ ; and  $x + y = 3$  in a 70% by weight aqueous ethylene glycol solution, from DuPont;  
 Surfactant no. 15 = ZONYL™ FSJ, a 40% by weight solution of a blend of  $F(CF_2CF_2)_{1-7}CH_2CH_2O]_xP(O)(ONH_4)_y$  where  $x = 1$  or  $2$ ;  $y = 2$  or  $1$ ; and  $x + y = 3$  with a hydrocarbon surfactant in 25% by weight solution of isopropanol in water, from DuPont;  
 Surfactant no. 16 = ZONYL™ FSP, a 35% by weight solution of  $[F(CF_2CF_2)_{1-7}CH_2CH_2O]_xP(O)(ONH_4)_y$  where  $x = 1$  or  $2$ ;  $y = 2$  or  $1$  and  $x + y = 3$  in 69.2% by weight solution of isopropanol in water, from DuPont;  
 Surfactant no. 17 = ZONYL™ UR:  $[F(CF_2CF_2)_{1-7}CH_2CH_2O]_xP(O)(OH)_y$  where  $x = 1$  or  $2$ ;  $y = 2$  or  $1$  and  $x + y = 3$ , from DuPont;  
 Surfactant no. 18 = ZONYL™ TBS: a 33% by weight solution of  $F(CF_2CF_2)_{3-8}CH_2CH_2SO_3H$  in a 4.5% by weight solution of acetic acid in water, from DuPont;  
 Surfactant no. 19 = ammonium salt of perfluoro-octanoic acid from 3M

#### Binder

10      According to a sixth embodiment of the layer configuration, according to the present invention, the layer configuration further contains a binder.

## Crosslinking agent

According to a seventh embodiment of the layer configuration, according to the present invention, the layer configuration further  
5 contains a cross-linking agent.

## Electroluminescent phosphors

According to an eighth embodiment of the layer configuration,  
10 according to the present invention, the layer configuration further comprises a layer of an electroluminescent phosphor.

According to a ninth embodiment of the layer configuration, according to the present invention, the layer configuration further comprises a layer of an electroluminescent phosphor, wherein the  
15 electroluminescent phosphor belongs to the class of II-VI semiconductors e.g. ZnS, or is a combination of group II elements with oxidic anions, the most common being silicates, phosphates, carbonates, germanates, stannates, borates, vanadates, tungstates and oxysulphates. Typical dopants are metals and all the rare  
20 earths e.g. Cu, Ag, Mn, Eu, Sm, Tb and Ce.

According to a tenth embodiment of the layer configuration, according to the present invention, the layer configuration further comprises a layer of an electroluminescent phosphor, wherein the electroluminescent phosphor is encapsulated with a transparent  
25 barrier layer against moisture e.g. Al<sub>2</sub>O<sub>3</sub> and AlN. Such phosphors are available from Sylvania, Shinetsu polymer KK, Durel, Acheson and Toshiba. An example of coatings with such phosphors is 72X, available from Sylvania/GTE, and coatings disclosed in US 4,855,189.

30 According to an eleventh embodiment of the layer configuration, according to the present invention, the layer configuration further comprises a layer of an electroluminescent phosphor, wherein the electroluminescent phosphor is ZnS doped with manganese, copper or terbium or CaGa<sub>2</sub>S<sub>4</sub> doped with cerium, e.g. the  
35 electroluminescent phosphor pastes supplied by DuPont: LUXPRINT™ type 7138J, a white phosphor; LUXPRINT™ type 7151J, a green-blue phosphor; and LUXPRINT™ type 7174J, a yellow-green phosphor; and ELECTRODAG™ EL-035A supplied by Acheson.

According to a twelfth embodiment of the layer configuration,  
40 according to the present invention, the layer configuration further comprises a layer of an electroluminescent phosphor, wherein the

electroluminescent phosphor is a zinc sulphide phosphor doped with manganese and encapsulated with AlN.

#### Dielectric layer

5

According to a thirteenth embodiment of the layer configuration, according to the present invention, the layer configuration further comprises a dielectric layer.

Any dielectric material may be used in the dielectric layer, with yttria and barium titanate being preferred e.g. the barium titanate paste LUXPRINT™ type 7153E high K dielectric insulator supplied by DuPont and the barium titanate paste ELECTRODAG™ EL-040 supplied by Acheson. A positive ion exchanger may be incorporated into the dielectric layer to capture any ions dissolving escaping from the phosphor of the light-emitting layer. The amount of ion exchanger in the dielectric layer has to be optimized so that it has a maximum effectiveness in reducing black spots while not reducing the initial brightness level. It is therefore preferred to add 0.5 to 50 parts by weight of ion exchanger to 100 parts by weight of the total amount of resin and dielectric material in the dielectric layer. The ion exchanger may be organic or inorganic.

Suitable inorganic ion exchangers are hydrated antimony pentoxide powder, titanium phosphate, salts of phosphoric acid and silicic acid and zeolite.

25

#### Support

According to a fourteenth embodiment of the layer configuration, according to the present invention, the support is transparent or translucent.

According to a fifteenth embodiment of the layer configuration, according to the present invention, the support is a polymeric film, silicon, a ceramic, an oxide, glass, polymeric film reinforced glass, a glass/plastic laminate, a metal/plastic laminate, optionally treated paper and laminated paper.

According to a sixteenth embodiment of the layer configuration, according to the present invention, the support is provided with a subbing layer or other adhesion promoting means to aid adhesion to the substantially transparent layer configuration.

According to a seventeenth embodiment of the layer configuration, according to the present invention, the support is a transparent or translucent polymer film.

40

A transparent or translucent support suitable for use with the electroconductive or antistatic layers, according to the present invention, may be rigid or flexible and consist of a glass, a glass-polymer laminate, a polymer laminate, a thermoplastic polymer  
5 or a duroplastic polymer. Examples of thin flexible supports are those made of a cellulose ester, cellulose triacetate, polypropylene, polycarbonate or polyester, with poly(ethylene terephthalate), poly(ethylene naphthalene-1,4-dicarboxylate), polystyrene, polyethersulphone, polycarbonate, polyacrylate,  
10 polyamide, polyimides, cellulose triacetate, polyolefins and poly(vinylchloride), optionally treated by corona discharge or glow discharge or provided with a subbing layer.

#### Electroluminescent devices

15

Aspects of the present invention are realized by an electroluminescent device comprising a layer configuration prepared according to the process, according to the present invention.

According to an eighteenth embodiment of the layer  
20 configuration, according to the present invention, the layer configuration is an electroluminescent device.

According to a nineteenth embodiment of the layer configuration, according to the present invention, the layer configuration is a light emitting diode.

25 Thin film electroluminescent devices (ELDs) are all characterized by one (or more) electroluminescent active layer(s) sandwiched between two electrodes. Optionally a dielectric layer may also be part of the sandwich.

Thin film ELDs can be subdivided into organic and inorganic  
30 based ELDs. Organic-based thin film ELDs can be subdivided into low molecular weight organic devices including oligomers (Organic Light Emitting Diodes (OLEDs)) and high molecular weight organic devices (Polymer Light Emitting Diodes (PLEDs)). The inorganic ELDs on the other hand can be further subdivided into the High Voltage  
35 Alternating Current (HV-AC) ELDs and the Low Voltage Direct Current (LV-DC) ELDs. The LV-DC ELDs include Powder ELDs (DC-PEL Devices or DC-PELDs) and thin film DC-ELDs, hereinafter called Inorganic Light Emitting Diodes (ILEDs).

The basic construction of organic ELDs (PLED and OLED)  
40 comprises following layer arrangement: a transparent substrate (glass or flexible plastic), a transparent conductor, e.g. Indium Tin Oxide (ITO), a hole transporting layer, a luminescent layer,



and a second electrode, e.g. a Ca, Mg/Ag or Al/Li electrode. For OLEDs the hole transporting and luminescent layers are 10-50 nm thick and applied by vacuum deposition, whereas for PLEDs the hole transporting layer is usually about 40 nm thick and the luminescent layer is usually about 100 nm thick and applied by spin coating or other non-vacuum coating techniques. A direct voltage of 5-10 V is applied between the electrodes and light emission results from holes and electrons being injected from the positive and negative electrodes respectively combining in the luminescent layer thereby producing the energy to excite the luminescent species to emit light.

In OLEDs the hole transporting layer and electroluminescent layer consist of low molecular organic compounds e.g. N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine can be used as the hole transporter and aluminium (III) 8-hydroxyquinoline complex, polyaromatics (anthracene, perylene and stilbene derivatives) and polyheteroaromatics (oxazoles, oxadiazoles, thiazoles etc.) can be used as electroluminescent compounds. In PLEDs electroluminescent compounds that can be used are polymers like the non-conjugated poly(N-vinylcarbazole) derivatives (PVK) or conjugated polymers like poly(p-phenylene vinylenes) (PPV), polyfluorenes, poly(3-alkylthiophene) and poly(p-phenylene ethynylenes).

Low voltage DC PEL Devices generally comprise a transparent substrate, a transparent conductor (ITO), a doped ZnS phosphor layer (20µm), and a top electrode of evaporated aluminium. The phosphor layer is applied by means of the doctor blade technique or screen printing on an ITO conducting layer. Then an aluminium electrode is applied by evaporation. Upon applying a direct current voltage of several volts (ITO positive), holes start moving towards the aluminium electrode, thereby creating an insulating region (about 1 µm in thickness) next to the ITO layer within one minute or so. This results in a current drop which is associated with the onset of light emission. This process has been called the forming process. In the thin high resistive phosphor layer thereby formed, high electric fields occur and electroluminescence is already possible at low voltages (typically between 10 and 30 V).

In hybrid LEDs, inorganic emitting so-called quantum dots are used in combination with organic polymers with charge transporting properties and in some cases also emitting properties. Hybrid LEDs with CdSe nano-particles have been reported by Colvin et al. [see Nature, volume 370, pages 354-357, (1994)], Dabbousi et al. [see Appl. Phys. Lett., volume 66, pages 1316-1318 (1995), and Gao et

al. [see J. Phys. Chem. B, volume 102, pages 4096-4103 (1998)], herein incorporated by reference.

Light emitting devices with ZnS:Cu nano-crystals and a non-semiconducting polymer have been reported by Huang et al. [see 5 Appl. Phys. Lett., volume 70, pages 2335-2337 (1997)] and Que et al. [see Appl. Phys. Lett., volume 73, pages 2727-2729 (1998)], herein incorporated by reference, with turn on voltages below 5 V.

#### Photovoltaic devices

10

Aspects of the present invention are realized by a photovoltaic device comprising a layer configuration prepared according to the process, according to the present invention.

According to a twentieth embodiment of the layer 15 configuration, according to the present invention, the layer configuration is a photovoltaic device.

According to a twenty-first embodiment of the layer configuration, according to the present invention, the layer configuration further comprises at least one photovoltaic layer. 20 The photovoltaic layer may be organic layer, a hybrid inorganic and organic layer or an inorganic layer.

According to a twenty-second embodiment of the layer configuration, according to the present invention, the layer configuration is a solar cell.

25 Photovoltaic devices incorporating the layer configuration, according to the present invention, can be of two types: the regenerative type which converts light into electrical power leaving no net chemical change behind in which current-carrying electrons are transported to the anode and the external circuit and 30 the holes are transported to the cathode where they are oxidized by the electrons from the external circuit and the photosynthetic type in which there are two redox systems one reacting with the holes at the surface of the semiconductor electrode and one reacting with the electrons entering the counter-electrode, for example, water is 35 oxidized to oxygen at the semiconductor photoanode and reduced to hydrogen at the cathode. In the case of the regenerative type of photovoltaic cell, as exemplified by the Graetzel cell, the electron transporting medium may be a nano-porous metal oxide semiconductor with a band-gap of greater than 2.9 eV, such as 40 titanium dioxide, niobium(V) oxide, tantalum(V) oxide and zinc oxide, the hole transporting medium may be a liquid electrolyte supporting a redox reaction, a gel electrolyte supporting a redox

reaction, an organic hole transporting material, which may be a low molecular weight material such as 2,2',7,7'-tetrakis(N,N-di-p-methoxyphenyl-amine)9,9'-spirobifluorene (OMeTAD) or triphenylamine compounds or a polymer such as PPV-derivatives, poly(N-vinylcarbazole) etc., or inorganic semiconductors such as CuI, CuSCN etc. The charge transporting process can be ionic as in the case of a liquid electrolyte or gel electrolyte or electronic as in the case of organic or inorganic hole transporting materials.

Such regenerative photovoltaic devices can have a variety of internal structures in conformity with the end use. Conceivable forms are roughly divided into two types: structures which receive light from both sides and those which receive light from one side. An example of the former is a structure made up of a transparently conductive layer e.g. an ITO-layer or a PEDOT/PSS-containing layer and a transparent counter electrode electrically conductive layer e.g. an ITO-layer or a PEDOT/PSS-containing layer having interposed therebetween a photosensitive layer and a charge transporting layer. Such devices preferably have their sides sealed with a polymer, an adhesive or other means to prevent deterioration or volatilization of the inside substances. The external circuit connected to the electrically-conductive substrate and the counter electrode via the respective leads is well-known.

Alternatively the spectrally sensitized nano-porous metal oxide, according to the present invention, can be incorporated in hybrid photovoltaic compositions such as described in 1991 by Graetzel et al. in Nature, volume 353, pages 737-740, in 1998 by U. Bach et al. [see Nature, volume 395, pages 583-585 (1998)] and in 2002 by W. U. Huynh et al. [see Science, volume 295, pages 2425-2427 (2002)]. In all these cases, at least one of the components (light absorber, electron transporter or hole transporter) is inorganic (e.g. nano-TiO<sub>2</sub> as electron transporter, CdSe as light absorber and electron transporter) and at least one of the components is organic (e.g. triphenylamine as hole transporter or poly(3-hexylthiophene) as hole transporter).

### Transistors

Aspects of the present invention are realized by a transistor comprising a layer configuration prepared according to the process, according to the present invention.

According to a twenty-third embodiment of the layer configuration, according to the present invention, the layer

configuration further comprises a layer with one or more of the electron transporting or hole transporting components described above, but within such a configuration that it can be used as a transistor. The semiconductor can be n-type, p-type or both  
 5 (ambipolar transistor) and can be either organic or inorganic.

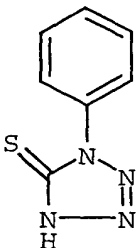
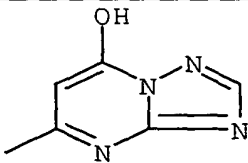
#### Industrial application

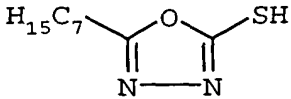
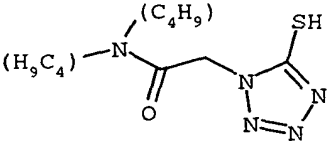
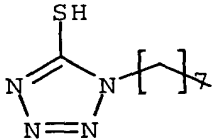
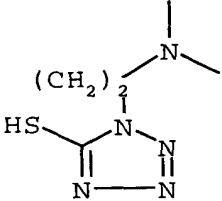
Layer configurations comprising at least a first layer  
 10 comprising an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver can be used in a wide range of electronic devices such as photovoltaic devices, solar cells, batteries, capacitors, light emitting diodes, organic and inorganic electroluminescent devices, smart windows,  
 15 electrochromic devices, sensors for organic and bio-organic materials and field effect transistors [see also chapter 10 of the Handbook of Oligo- and Polythiophenes, Edited by D. Fichou, Wiley-VCH, Weinheim (1999)].

20 The invention is illustrated hereinafter by way of EXAMPLES. The percentages and ratios given in these examples are by weight unless otherwise indicated.

Ingredients used in the comparative experiments of EXAMPLE 2:

25

	Structural formula	
STAB01		1-phenyl-5-mercapto-tetrazole
STAB02		sodium tartrate
STAB03		thiourea
STAB04	Na <sub>2</sub> S	sodium sulphide
STAB05		5-methyl-s-triazolo[1,5-a]pyrimidin-7-ol

STAB06		
STAB07		
STAB08	$\text{Na}^+$ 	
STAB09		

## EXAMPLE 1

Conductive Ag-pattern made by development of a silver halide  
5 emulsion with an outermost PEDOT/PSS layer

Preparation of the photographic emulsion layer:

A photographic AgCl(63.29%)Br(36.31%)I(0.40%) emulsion in gelatine  
10 was prepared using the double jet precipitation technique. The average silver halide particle size was 300 nm. After the precipitation step the emulsion was washed and different amounts of gelatine were added to yield the gelatine to AgNO<sub>3</sub> (g/g) ratio's listed in Table 1. This emulsion was chemically ripened and was  
15 spectrally sensitized to render the emulsion sensitive to He/Ne laser exposure. The emulsion was coated on a subbed 100µm thick polyethylene terephthalate support to a coverage equivalent to 5 g AgNO<sub>3</sub> per square meter. This is photographic material A.

20 Surface resistance measurements:

The surface resistance measurements were carried out as follows: the layer electrode configurations were cut into strips 3.5 cm in width to ensure perfect positioning of the electrode

material; parallel copper electrodes each 35 mm long, 3 mm wide and 35 mm apart, capable of forming line contacts and mounted on a TEFLON™ insulator were brought into contact with the outermost conductive layer of the strip giving a contacting area of  $3.5 \times 3.5$  cm<sup>2</sup>, a constant contact force being ensured by placing a 4 kg weight on the TEFLON™ mounting; and the surface resistance was then directly measured using a Fluke-77 III Multimeter.

The surface resistances determined for different gelatine to AgNO<sub>3</sub> ratios after full area exposure with an AGFA-GEVAERT™ AVANTRA recorder and subsequent development in the AGFA-GEVAERT™ IPDplus developer, fixed in an AGFA-GEVAERT™ G333 fixer and finally rinsed in water are given in Table 1.

Table 1:

Material	Gelatine/AgNO <sub>3</sub> (g/g)	Surface resistance [ $\Omega$ /square]
A1	0.40	$> 10^7$
A2	0.30	60
A3	0.20	20
A4	0.18	15
A5	0.14	10

Table 1 shows that the lower the gelatine content the lower the surface resistance. This can be explained by developed silver particles touching each other at low gelatine contents and hence creating a conductive path. Material A5 yields the highest surface conductance, but for convenience reasons, material A4 was used in the further examples.

Preparation of the PEDOT/PSS dispersion:

EP-A 686662 (US 5,766,515) discloses in the example the preparation of a 1.2% PEDOT/PSS dispersion in water. 15 mL of a 2% solution of ZONYL™ FSO100 in water, 1.25 g of Z6040, a silane from DOW CORNING and 25 g of diethyleneglycol were added to 106 g of this dispersion to give the PEDOT/PSS dispersion used in the following EXAMPLES.

Preparation of double layer electrode configuration of Material B:

The unexposed Material A4 was coated with the PEDOT/PSS dispersion to a wet thickness of 50  $\mu$ m and then dried for 20 minutes at 120°C. The surface resistivity of the PEDOT/PSS layer was about 500

$\Omega$ /square. The resulting layer configuration was then exposed with the AGFA-GEVAERT™ AVANTRA recorder with the patterns shown in Figure 1 and developed as described above.

5 Preparation of double layer electrode configuration of Material C:

The PEDOT/PSS-dispersion was coated on the processed material A4 to a wet thickness of 50  $\mu$ m and then dried for 20 minutes at 120°C, thereby producing Material C. The surface resistance of the  
10 PEDOT/PSS layer was about 500  $\Omega$ /square in the non-exposed regions material A4.

Evaluation of Materials A4 (exposed and developed), B and C:

15 The surface resistances determined as described above are given in Table 2 for the double layer electrode configurations with a developed silver pattern coated with a PEDOT/PSS outermost layer of Materials B and C, together with that for the exposed and developed Material A4 without an PEDOT/PSS outermost layer as a  
20 control material.

The optical density of the layer configurations were determined in transmission using a MacBeth™ TD924 densitometer with a visible filter for layer configurations without photographic treatment, in pattern type (d) in which no silver was developed and  
25 in pattern (a) in which silver was developed over the whole 3 cm x 3 cm area without deducting the density of the support. These measurements were then used to calculate the overall optical density for patterns (b) and (c). The optical density results are also given in Table 2.

30 From Table 2 it can be concluded that (1) it is possible to expose the PEDOT/PSS layer to the IPDplus developer and G333 fixer with only minor losses in surface conductivity and (2) the Ag-lines increase the "apparent" surface conductivity. Due to the measurement set-up, only the PEDOT/PSS is contacted (top-layer).  
35 From the high surface conductivity values, the PEDOT/PSS-Ag contact appears to be Ohmic in nature.

If the PEDOT/PSS coating is applied before the exposure and development, it functions as a protective coating and therefore material B is in most cases preferred over material C, because this  
40 allows for automatic handling (exposure and development) without any danger of damaging the material.

Table 2:

Control material	Description	Pattern used from Fig 1		trans-mission O.D.	Surface resistance [ $\Omega$ /square]
		type	description		
A4	Without any photographic treatment	-	-	-	$> 2 \times 10^7$
A4	After exposure and development	a	Solid area	3.70	15
A4	After exposure and development	b	1 mm lines, 10 mm spacing	0.35*	100
A4	After exposure and development	c	150 $\mu$ m lines, 5 mm spacing	0.13*	340
A4	After exposure and development	d	No Ag developed	0.03	$> 2 \times 10^7$
Invention material					
B	Without any photographic treatment	-	-	-	450
B	After exposure and development	a	Solid area	3.90	13
B	After exposure and development	b	1 mm lines, 10 mm spacing	0.48*	150
B	After exposure and development	c	150 $\mu$ m lines, 5 mm spacing	0.25*	360
B	After exposure and development	d	No Ag developed	0.15	470
C	Without any photographic treatment	-	-	-	500
C	After exposure and development	a	Solid area	3.80	14
C	After exposure and development	b	1 mm lines, 10 mm spacing	0.45*	108
C	After exposure and development	c	150 $\mu$ m lines, 5 mm spacing	0.22*	360
C	After exposure and development	d	No Ag developed	0.11	720

\* calculated value

Conductive Ag-pattern made by DTR with conductive PEDOT/PSS on top



Preparation of the control material, Material D:

The preparation of the physical development nuclei (PdS) is described in the example of EP-A 0769 723. From this example  
5 solutions A1, B1 and C1 were used to prepare the nuclei. To 1000 mL of this PdS dispersion 10 g of a 10 g/L water solution of Aerosol™ OT from American Cyanamid and 5 g of a 50 g/L solution of perfluorcaprylamide-polyglycol were added. This dispersion was then coated to a wet layer thickness of 13.5 µm on a poly(ethylene  
10 terephthalate) support with a 4 µm thick gelatine subbing layer and then dried for 60 minutes at 25°C. This is material D.

Preparation of material E:

15 The above-described PEDOT/PSS dispersion was used to coat material D to a wet thickness of 40 µm and was then dried for 15 minutes at 100°C, thereby producing material E.

Preparation of the transfer emulsion layer:

20

The preparation of the silver chlorobromide emulsion and the preparation of the transfer emulsion layer was as disclosed in EP-A 769 723 except that the coverage of silver halide applied was equivalent to 1.25 g/m<sup>2</sup> of AgNO<sub>3</sub> instead of 2 g/m<sup>2</sup> thereof.

25

Exposure and development of Materials D and E:

The transfer emulsion layer was exposed image-wise as shown in Figure 1 and processed in contact with the receiver (Material D and  
30 material E) at 25°C for 10s with a AGFA-GEVAERT™ CP297 developer solution.

Preparation of the double layer electrode configuration:

35 Processed material D was coated with the above-described PEDOT/PSS-dispersion to a wet-layer thickness of 50 µm and then dried for 20 minutes at 120°C. The surface resistivity of the PEDOT/PSS layer was about 500 Ohm/Sq in the non-exposed areas of material D. Material F was thereby prepared.

40

## Evaluation of materials D, E and F:

The surface resistances and optical densities (complete material) after exposure and development according to the patterns shown in Figure 1 are given in Table 3.

Table 3:

Control material	Description	Pattern used from Fig 1		trans-mission O.D.	Surface resistance [ $\Omega$ /square]
		type	description		
D	Without any photographic treatment	-	-	0.04	$> 2 \times 10^7$
D	After transfer reaction	a	Solid area	2.50	2.1
D	After transfer reaction	b	1 mm lines, 10 mm spacing	0.35*	16
D	After transfer reaction	c	150 $\mu$ m lines, 5 mm spacing	0.20*	109
D	After transfer reaction	d	No Ag developed	0.04	$> 2 \times 10^7$
Invention material					
E	Without any photographic treatment	-	-	0.09	500
E	After transfer reaction	a	Solid area	2.30	5.2
E	After transfer reaction	b	1 mm lines, 10 mm spacing	0.33*	37
E	After transfer reaction	c	150 $\mu$ m lines, 5 mm spacing	0.19*	165
E	After transfer reaction	d	No Ag developed	0.07	800
F	Without any photographic treatment	-	-	0.10	650
F	After transfer reaction	a	Solid area	2.50	2.3
F	After transfer reaction	b	1 mm lines, 10 mm spacing	0.35*	18
F	After transfer reaction	c	150 $\mu$ m lines, 5 mm spacing	0.20*	120
F	After transfer reaction	d	No Ag developed	0.09	750

\* calculated values

10

From Table 3 it can be concluded that it is possible to (1) transfer Ag-salts through the PEDOT/PSS layer, (2) expose the PEDOT/PSS layer to the AGFA-GEVAERT™ CP297 developer with only a minor loss in surface conductivity without affecting the optical transparency and (3) the Ag-lines increase the "apparent" surface conductivity significantly.

Only the outermost PEDOT/PSS layer is contacted in the surface resistance measurements. From the high surface conductivity values, the PEDOT/PSS-Ag contact appears to be Ohmic in nature. If the PEDOT/PSS coating is applied before the exposure and  
5 development, it functions as a protective coating and therefore material E is in most cases preferred over material F, because this allows for automatic handling (exposure and development) without any danger of damaging the material.

- 10 Improving of the surface conductance of the  $\text{Ag}^0$ -image by etching in presence of halide ions followed by a chemical development

Due to the fact that the DTR process is a physical development, the resulting  $\text{Ag}^0$ -particles are smooth and rounded. Chemical  
15 development, which is more explosive, results in a higher degree of particle overlap and particle touching and hence will result in patterns with higher conductivity. However, this type of development does not take place in a DTR process. In order to improve the surface conductance of a  $\text{Ag}^0$ -image obtained by the DTR-  
20 process, the conductive  $\text{Ag}^0$ -pattern obtained by the DTR process was further processed by first treating it with an etching solution containing an oxidizer and halide ions (thereby partially oxidizing the  $\text{Ag}^0$  to  $\text{Ag}^+$  which is present as  $\text{AgCl}$ ,  $\text{AgBr}$  or  $\text{AgBrCl}$  depending upon the halides used), then developing with a Graphic developer  
25 which brought about explosive or chemical development of the newly formed silver halide crystals and finally fixing and washing. When this process was applied to freshly produced processed material D with pattern "a" using AGFA-GEVAERT™ IPDplus developer and AGFA-GEVAERT™ G333 fixer an up to 18% decrease in surface resistance (= 30 18% increase in surface conductance) was realized. The etching bath compositions and etching times are given in Table 4.

Table 4:

Bath nr	Bath composition				Etching time (s)
	KMnO <sub>4</sub> [g/L]	K <sub>4</sub> Fe(CN) <sub>6</sub> [g/L]	KCl [g/L]	KBr [g/L]	
1	-	1	-	10	30
2	-	1	10	-	30
3	-	0.1	-	10	30
4	-	0.1	10	-	30
5	0.01	-	-	10	30
6	0.01	-	10	-	30
7	0.005	-	-	10	30
8	0.005	-	10	-	30
9	0.01	-	5	-	120
10	0.01	-	10	-	120
11	0.01	-	25	-	120
12	0.01	-	-	5	30
13	0.01	-	-	10	30
14	0.01	-	-	25	30
15	0.01	-	2.5	2.5	30
16	0.01	-	5	5	30
17	0.01	-	10	10	30
18	0.01	-	2.5	2.5	60
19	0.01	-	5	5	60
20	0.01	-	10	10	60
21	0.01	-	2.5	2.5	120
22	0.01	-	5	5	120
23	0.01	-	10	10	120

The optical density was measured with a MacBeth™ densitometer  
 5 TD904 with a visible filter. The surface resistances and optical  
 densities obtained are given in Table 5.

From Table 5 it is clear that the kind and amount of oxidising  
 agent used is very important: an oxidising agent which is too  
 strong or too concentrated will destroy the conductive pattern too  
 10 rapidly. If the oxidising agent is too weak or too dilute, almost  
 nothing will happen. Also the amount and kind of halide ions is  
 important as can be seen from Table 5.

Table 5:

Bath nr	$D_{\max}$		Surface resistance [ $\Omega$ /square]		
	before etching	etching after + development	before etching	after etching + development	% change
1	2.84	2.75	3.7	3.5	-7
2	2.90	2.88	2.7	2.9	+5
3	2.92	2.87	2.7	3.0	+10
4	3.00	2.89	3.0	2.9	-5
5	2.48	2.27	2.5	6.4	+156
6	2.69	2.61	2.5	2.4	-4
7	2.52	2.65	2.5	2.7	+8
8	2.76	2.52	2.5	2.3	-8
9	2.49	2.36	2.7	2.7	0
10	2.50	2.38	3.0	2.6	-13
11	2.48	2.44	2.8	2.8	0
12	2.84	2.80	2.6	2.4	-8
13	2.72	2.63	3.2	3.3	+3
14	2.55	2.48	2.3	2.3	0
15	2.45	2.31	3.4	3.0	-12
16	2.47	2.36	3.1	2.8	-10
17	2.46	2.23	3.3	3.0	-9
18	2.50	2.33	3.3	3.0	-9
19	2.38	2.23	3.2	2.8	-13
20	2.48	2.32	3.4	2.8	-18
21	2.47	2.33	3.3	3.0	-9
22	2.52	2.37	3.2	2.8	-13
23	2.48	2.35	3.2	2.7	-16

5 Recovery of the PEDOT/PSS conductivity after IPDplus  
processing by means of re-oxidizing the PEDOT/PSS layer

The surface resistance of the outermost PEDOT/PSS-layer in Material B was not substantially increased upon 30s contact with the AGFA-GEVAERT™ IPDplus developer, but the surface resistance of the  
10 PEDOT/PSS-layer of the AGFA-GEVAERT™ ORGACON film increased from 500  $\Omega$ /square to ~3000  $\Omega$ /square upon 30s contact therewith. It has been found, however, that the original surface resistance can be largely recovered by treatment with solutions of particular oxidizing agents for 30 s at 25°C. The compositions of the  
15 solutions of oxidizing agent used and the surface resistances results obtained before contact with the IPDplus developer, after contact with the IPDplus developer and after subsequent contact with the particular oxidizing solution are given in Table 6.

Table 6:

solution of oxidising agent in water (% by weight)	Surface resistance [ $\Omega$ /square]		
	before processing in IPDplus (35°C & 30s)	after processing in IPDplus (35°C & 30s)	after processing in oxidising agent solution
FeCl <sub>3</sub> (0.1%)	503	3270	1608
FeCl <sub>3</sub> (2%)	452	3015	1440
H <sub>2</sub> O <sub>2</sub> (2%)	466	3450	2963
H <sub>2</sub> O <sub>2</sub> (10%)	485	3270	2238
K <sub>3</sub> Fe(CN) <sub>6</sub> (0.1%)	459	3075	1722
K <sub>3</sub> Fe(CN) <sub>6</sub> (2%)	549	3600	1607
Dimethylsulfoxide(0.1%)	513	2385	1793
HNO <sub>3</sub> (0.1%)	449	2160	1299
Na <sub>2</sub> S <sub>2</sub> O <sub>8</sub> (2%)	432	2130	1400
Succinic acid (0.1%)	440	2400	1781
Succinic acid (2%)	543	2835	1514

5 The best results were realized with aqueous solutions of Na<sub>2</sub>S<sub>2</sub>O<sub>8</sub> and FeCl<sub>3</sub> with which the surface resistance after contact with the IPDplus developer decreased by a factor of 2 to ~1500  $\Omega$ /square, but this was still a factor of 3 above the surface resistance of the ORGACON film prior to contact with IPDplus developer.

10

## EXAMPLE 3

Conductive Ag-pattern made by Diffusion Transfer Reaction with patterned conductive PEDOT/PSS on top.

15

Sometimes it is necessarily to have a patterned transparent conductive layer on top of a high conductive metallic pattern (e.g. EXAMPLE 5). This can be done by applying patterned the PEDOT/PSS on top of the emulsion layer (as described in example 1) prior to  
 20 exposure and development or applying patterned PEDOT/PSS on top of the nuclei layer (as described in example 2) prior to the diffusion transfer process. Analogously, as was described in examples 1 and 2 (comparison), the patterned PEDOT/PSS can also be applied after the formation of the Ag-pattern. The patterning of the PEDOT/PSS can be  
 25 subtractive by destroying its conductivity (e.g. EP-A 1054414, EP-A 1079397) or additive by using printing techniques like flexographic

printing, screen printing, tampon printing, off set printing and ink jet printing.

Preparation of the control material, Material G:

5

To 1000 mL of the above described PdS dispersion 10 mL of a 50 g/L in water solution of Antarox CO630 from GAF was added. This dispersion was then coated to a wet-layer thickness of 13.5  $\mu\text{m}$  on a PET substrate with a 2  $\mu\text{m}$  thick gelatine subbing layer and was then  
10 dried for 60 minutes at 25°C to give Material G.

Preparation of the screen print paste of PEDOT/PSS:

The screen print paste was prepared by adding 3.47 kg of 1,2-  
15 propandiol and 0.38 kg of diethylene glycol to 2.56 kg of a 1.2% by weight dispersion of PEDOT/PSS with a weight ratio of PEDOT to PSS of 1:2.4 in a reactor, then distilling off 1.5 L of water by heating with an oil bath at 62°C under stirring at a vacuum which varied between 31 and 55 mbar over a period of 234 minutes, cooling  
20 the resulting mixture to 20°C and then distilling off a further 0.49 L of water by heating with an oil bath at 60.5°C with stirring at a vacuum which varied between 24 and 26 mbar over a period of 287 minutes. The water content in the 3.8 kg of paste produced, as determined by the Karl Fischer method, was 3.9% by weight.

25 To 297 g of the obtained paste 1.5 g of 2-glycidoxypropyl-trimethoxysilane, 0.75 g of ZONYL™ FSO (ZONYL™ FSO is a 50% by wt solution of ZONYL™ FSO100 a mixture of 50% by wt of water and 50% by wt of ethylene glycol) and 0.75 g of silicone antifoam agent X50860A was added to give a screen printing paste.

30

Preparation of Material H:

The screen printing paste was silk screen printed with a manual press and a P120 screen onto material G to cover the final images  
35 shown in Figure 1 thereby giving Material H.

Exposure and development of Materials G and H:

The transfer emulsion layer was exposed image-wise as shown in  
40 Figure 1 and processed in contact with the receiver (Material G and Material H) at 25°C for 10s with an AGFA-GEVAERT™ CP297 developer solution.

Preparation of double layer electrode configuration of Material I:

The screen printing paste was silk screen printed with a manual press and a P120 screen onto the processed material G so as to cover the image as shown in Figure 1, thereby producing Material I.

Evaluation of Materials G, H and I:

- 10 The surface resistances and optical densities (complete material) after exposure and development according to the pattern of Figure 1 are given in Table 7.

Table 7:

15

Control material	Description	Pattern used from Fig 1		trans-mission O.D.	Surface resistance [ $\Omega$ /square]
		type	description		
G	Without any photographic treatment	-	-	0.03	$> 2 \times 10^7$
G	After transfer reaction	a	Solid area	2.35	2.2
G	After transfer reaction	b	1 mm lines, 10 mm spacing	0.24*	18
G	After transfer reaction	c	150 $\mu$ m lines, 5 mm spacing	0.10*	140
G	After transfer reaction	d	no Ag developed	0.03	$> 2 \times 10^7$
Invention material					
H	Without photographic treatment	-	-	0.10	1500
H	After transfer reaction	a	Solid area	2.10	8.5
H	After transfer reaction	b	1 mm lines, 10 mm spacing	0.28*	225
H	After transfer reaction	c	150 $\mu$ m lines, 5 mm spacing	0.16*	2200
H	After transfer reaction	d	No Ag developed	0.12	18000
I	Without any photographic treatment	-	-	0.13	1250
I	After transfer reaction	a	Solid area	2.38	4.4
I	After transfer reaction	b	1 mm lines, 10 mm spacing	0.35*	30
I	After transfer reaction	c	150 $\mu$ m lines, 5 mm spacing	0.20*	100
I	After transfer reaction	d	No Ag developed	0.09	1250

\* calculated values



The results in Table 7 show that it is feasible to construct a double layer electrode by this method, although the surface resistance of the PEDOT/PSS screen print paste was adversely affected by the AGFA-GEVAERT™ CP297 developing solution, the surface resistance increasing from 1500  $\Omega$ /square to 18000  $\Omega$ /square.

#### EXAMPLE 4

10

Conductive PEDOT/PSS with conductive Ag-pattern made by Diffusion Transfer Reaction on top.

Preparation of the control material, Material J:

15

The above-described PEDOT/PSS dispersion was used to coat a polyethylene terephthalate support with a 4  $\mu$ m gelatine subbing layer to a wet thickness of 40  $\mu$ m and was then dried for 15 minutes at 100°C, thereby producing material J.

20

Preparation of Material K:

To 1000 mL of the above described PdS dispersion 10 g of a 10 g/L water solution of Aerosol OT from American Cyanamid and 5 g of a 50 g/L solution of perfluorocaprylamidpolyglycol were added. This dispersion was then coated with a wet layer thickness of 13.5  $\mu$ m on material J and then dried for 60 minutes at 25°C. This is material K.

30 Exposure and development of Material K:

The transfer emulsion layer was exposed image-wise as shown in Figure 1 and processed in contact with the receiver (Material K) at 25°C for 10s with the AGFA-GEVAERT™ CP297 developer solution. The surface resistances and optical densities (complete material) after exposure and development according to the pattern of Figure 1 are given in Table 8.

Table 8 demonstrates the feasibility of a double layer electrode configuration with a Ag-conductive pattern on top of a conductive PEDOT/PSS-layer. The measured value of surface resistivity of the untreated material K is 5000  $\Omega$ /square instead of 500  $\Omega$ /square. It is also not > 20 M $\Omega$ /square. This indicates a

slight mixing of the layers and/or inhomogeneities in the PdS-layer. It is clear from the above description that the nuclei layer can also be applied in a patterned way.

s Table 8:

Control material	Description	Pattern used from Fig 1		trans-mission O.D.	Surface resistance [ $\Omega$ /square]
		type	description		
J	Without any photographic treatment	-	-	0.04	500
J	After dipping 10 s in AGFA-GEVAERT™ CP297 developer	-	-	0.04	620
Invention material					
K	Without any photographic treatment	-	-	0.06	5000
K	After transfer reaction	a	Solid area	2.20	2.9
K	After transfer reaction	b	1 mm lines, 10 mm spacing	0.25*	33
K	After transfer reaction	c	150 $\mu$ m lines, 5 mm spacing	0.12*	95
K	After transfer reaction	d	No Ag developed	0.07	1300

\* calculated values

#### EXAMPLE 5

10

Application of a conductive Ag-pattern coated with a patterned conductive PEDOT/PSS in the production of thin film solar cells

Figure 2 shows side (upper) and top (lower) views of a  
 15 sequential process for building up a module with a separate photovoltaic cell, two serially connected photovoltaic cells and three serially connected photovoltaic cells using a six step process in which:

20 A = a subbed support

B = a gelatin layer

C = a palladium sulfide nucleation layer

D = a conductive silver pattern

E = a highly conductive PEDOT/PSS-layer

25 F = a shunt resistance hindering layer

G = a photovoltaic blend

H = a lithium fluoride/aluminium electrode

In step 1 in which the subbed surface of a subbed poly(ethylene  
5 terephthalate) film A [the subbing layer represented by hatching]  
is coated with a gelatin layer B; step 2 in which a palladium  
sulfide nucleation layer C is applied to the gelatin layer B; step  
3 in which a diffusion transfer process is carried out in which a  
conductive silver pattern D is produced; step 4 in which the  
10 conductive silver pattern D is coated with a highly conductive  
PEDOT/PSS-layer E by e.g. screen printing, and optionally  
additionally with a shunt resistance hindering layer F, e.g. a  
PEDOT/PSS layer or a PEDOT-S/polycationic or polyanionic polymer  
with a higher surface resistance; step 5 in which layer E or F is  
15 coated with a photovoltaic blend, e.g. a blend of MDMO-PPV/PCBM G,  
by e.g. curtain coating, spincoating or screen printing; and step 6  
in which layer G is coated with a non-continuous lithium  
fluoride/aluminium layer forming a top electrode H.

This figure shows a way of using the multilayer configuration  
20 in the construction of a thin film solar cell module e.g. solar  
cells based on the bulk hetero junction principle. A double layer  
electrode (Ag-pattern - PEDOT/PSS) can be constructed by using the  
method described in EXAMPLE 2. This makes feasible the construction  
of cells with larger areas, because the charge will be collected in  
25 the conductive Ag-network.

#### EXAMPLE 6

Conceptual experiments were carried out with a recorder film  
30 with a gelatine to silver ratio of 0.014. Exposed areas of  $1 \times 3$   
 $\text{cm}^2$  as electrodes with a separation of  $40 \mu\text{m}$  gave conducting silver  
patterns upon processing by conventional graphic processing. The  
resulting electrode pattern had a surface resistance of 50 to 100  
ohm/square.

35 These electrodes were conditioned for 3 days at  $35^\circ\text{C}$  and a  
relative humidity of 80%. The aqueous solutions used for treating  
the electrodes prior to applying a potential of 100 V between  
neighbouring electrodes are listed in Table 9.

Table 9:

Solution nr.		Solution		
		active ingredient	conc. (%)	solvent
1	3777150	STAB01 (1-phenyl-5-mercapto-tetrazole)	1.0	water*
2	3777151	STAB01	0.1	water*
3	3777152	STAB01 + Antaro <sup>TM</sup> CO 630#	1.0 + 0.5	water
4	3777153	STAB01 + Antaro <sup>TM</sup> CO 630#	0.1 + 0.5	water
5	3777154	STAB02 (sodium tartrate)	10	water
6	3777155	STAB02 (sodium tartrate)	1	water
7	3777156	STAB03 (thiourea)	10	water
8	3777157	STAB03 (thiourea)	1	water
9	3777158	STAB04 (sodium sulphide)	10	water
10	3777159	STAB04 (sodium sulphide)	1	water
11	3777166	STAB05 (5-methyl-s-triazolo[1,5-a]pyrimidin-7-ol)	4.25	water
12	3777167	STAB05	0.425	water
13	3777168	STAB05	$1.7 \times 10^{-2}$	water
14	3777169	STAB05	$1.7 \times 10^{-4}$	water
15	3777170	STAB05	$1.7 \times 10^{-5}$	water
16	3777171	STAB05	$1.7 \times 10^{-6}$	water
17	3780150	STAB06	0.5	water
18	3780151	STAB06	0.05	water
19	3780152	STAB06	0.005	water
20	3780153	STAB07	0.5	water
21	3780154	STAB07	0.05	water
22	3780155	STAB07	0.005	water
23	3780156	STAB08	0.5	water
24	3780157	STAB08	0.05	water
25	3780158	STAB08	0.005	water
26	3780159	STAB09	0.5	water
27	3780160	STAB09	0.05	water
28	3780161	STAB09	0.005	water
29	3777161	PMT01	0.1	ethanol
30	3777172	PMT01	0.004	ethanol
31	3777173	PMT01	$4 \times 10^{-5}$	ethanol
32	3777174	PMT01	$4 \times 10^{-6}$	ethanol
33	3780162	PMT02	0.5	water
34	3780163	PMT02	0.05	water
35	3780164	PMT02	0.005	water
36	3780165	PMT03	0.5	water
37	3780166	PMT03	0.05	water
38	3780167	PMT03	0.005	water
39	3780168	PMT04	0.5	ethanol
40	3780169	PMT04	0.05	ethanol

41	3780170	PMT04	0.005	ethanol
42	3780171	PMT05	0.5	water
43	3780172	PMT05	0.05	water
44	3780173	PMT05	0.005	water
45	3780175	PMT06	0.05	water
46	3780176	PMT06	0.005	water
47	3780178	PMT07	0.05	water
48	3780179	PMT07	0.005	water
49	3780180	PMT08	0.5	water
50	3780181	PMT08	0.05	water
51	3780182	PMT08	0.005	water
52	3780183	PMT09	0.5	water
53	3780184	PMT09	0.05	water
54	3780185	PMT09	0.005	water
55	3780187	PMT10	0.5	water
56	3780188	PMT10	0.05	water
57	3780190	PMT11	0.05	water
58	3780191	PMT11	0.005	water
59	3780193	PMT12	0.05	water
60	3780194	PMT12	0.005	water
61	3780196	PMT13	0.05	water
62	3780197	PMT13	0.005	water
63	3780199	PMT14	0.05	water
64	3780200	PMT14	0.005	water

# a nonyl-phenyl-oxy- polyethyleneglycol(EO 9.5), from GAF

After treatment of the electrodes by dipping in the solution for 1 minute at 25°C, a potential of 100 V was applied between  
 5 neighbouring electrodes for 20 minutes. The result was viewed under a microscope and recorded photographically. The gap between the electrodes without pretreatment and before applying a potential was determined to be  $43.0 \pm 0.7 \mu\text{m}$ . Tables 10 and 11 record the  
 10 final gap width and general observations concerning silver dendrite formation after particular pretreatments and the subsequent application of a potential of 100 V for 20 minutes for the comparative experiments with STAB01 to STAB09 and for the invention experiments with PMT01 to PMT14 respectively.

Table 10:

Comparative experiment nr.		sol- ution nr.	result of applying 100 V for 20 min. between electrodes	
			final width of gap [ $\mu\text{m}$ ]	observations
1#	3777165	none	$25.8 \pm 1.0$	front formation
2*	3777164	none	$28.3 \pm 1.0$	front formation
3*	3780201	none	$43.1 \pm 1.2$	dendrites, but no front formation
4	3777150	1	$23.6 \pm 1.8$	front formation
5	3777151	2	$21.5 \pm 2.5$	front formation
6	3777152	3	$25.5 \pm 2.9$	front formation
7	3777153	4	$41.8 \pm 0.7$	dendrite formation
8	3777154	5	$35.5 \pm 1.3$	front formation but loss of electrode contact
9	3777155	6	$33.6 \pm 1.7$	front formation
10	3777156	7	$27.8 \pm 1.9$	front formation
11	3777157	8	$26.2 \pm 2.9$	front formation
12	3777158	9	$22.1 \pm 4.1$	front formation but loss of electrode contact
13	3777159	10	$27.8 \pm 2.7$	front formation
14	3777166	11	$30.4 \pm 1.7$	front formation
15	3777167	12	$26.0 \pm 1.2$	front formation
16	3777168	13	$21.8 \pm 2.0$	zones with front formation/ zones with dendrites but no front formation
17	3777169	14	$23.5 \pm 3.1$ $43.8 \pm 0.7$	zones with front formation/ zones with dendrites but no front formation
18	3777170	15	$25.7 \pm 2.1$ $42.4 \pm 1.0$	zones with front formation/ zones with dendrites but no front formation
19	3777171	16	$22.6 \pm 2.3$	zones with front formation/ zones with dendrites but no front formation
20	3780150	17	$28.6 \pm 0.6$	front formation
21	3780151	18	$26.7 \pm 0.6$	front formation
22	3780152	19	$43.2 \pm 0.6$	dendrites, but no front formation
23	3780153	20	$23.4 \pm 0.9$	front formation
24	3780154	21	$24.9 \pm 1.1$	front formation
25	3780155	22	$24.6 \pm 0.6$	front formation
26	3780156	23	$32.2 \pm 2.3$	front formation
27	3780157	24	$43.3 \pm 0.6$	dendrites, but no front formation
28	3780158	25	$42.4 \pm 1.8$	dendrites, but no front formation
29	3780159	26	$42.7 \pm 1.7$	dendrites, but no front formation
30	3780160	27	$43.1 \pm 1.0$	occasional dendrites
31	3780161	28	$43.0 \pm 0.4$	occasional dendrites

# neither conditioning nor solution pretreatment prior to application of 100 V DC

s \* no solution pretreatment between conditioning and application of 100 V DC

Table 11:

Invention exper- iment nr.		sol- ution nr.	result of applying 100 V for 20 min. between electrodes	
			final width of gap [ $\mu$ m]	observations
1	3777161	29	$41.9 \pm 0.7$	almost no dendrite formation
2	3777172	30	$42.4 \pm 0.7$	almost no dendrite formation
3	3777173	31	$41.5 \pm 0.4$	almost no dendrite formation
4	3777174	32	$41.4 \pm 1.1$	occasional dendrites
5	3780162	33	$29.8 \pm 0.4$	front formation
6	3780163	34	$29.4 \pm 1.4$	front formation
7	3780164	35	$43.1 \pm 0.3$	dendrites, but no front formation
8	3780165	36	$42.9 \pm 0.4$	occasional dendrites
9	3780166	37	$42.6 \pm 0.7$	occasional dendrites
10	3780167	38	$43.3 \pm 0.75$	dendrites, but no front formation
11	3780168	39	$42.4 \pm 0.8$	almost no dendrite formation
12	3780169	40	$43.4 \pm 0.7$	occasional dendrites
13	3780170	41	$42.4 \pm 1.0$	dendrites, but no front formation
14	3780171	42	$43.9 \pm 0.8$	dendrites, but no front formation
15	3780172	43	$43.8 \pm 0.6$	almost no dendrite formation
16	3780173	44	$44.2 \pm 0.4$	almost no dendrite formation
17	3780175	45	$42.9 \pm 0.7$	dendrites, but no front formation
18	3780176	46	$43.4 \pm 0.7$	almost no dendrite formation
19	3780178	47	$43.5 \pm 1.0$	occasional dendrites
20	3780179	48	$43.2 \pm 0.9$	occasional dendrites
21	3780180	49	$25.4 \pm 2.3$	front formation
22	3780181	50	$43.4 \pm 0.8$	occasional dendrites
23	3780182	51	$43.7 \pm 0.4$	almost no dendrite formation
24	3780183	52	$43.3 \pm 0.7$	dendrites, but no front formation
25	3780184	53	$42.0 \pm 0.8$	occasional dendrites
26	3780185	54	$43.9 \pm 0.5$	almost no dendrite formation
27	3780187	55	$24.1 \pm 4.0$	front formation
28	3780188	56	$42.9 \pm 0.9$	dendrites, but no front formation
29	3780190	57	$25.6 \pm 3.3$	front formation
30	3780191	58	$43.0 \pm 0.5$	occasional dendrites
31	3780193	59	$23.4 \pm 3.0$	front formation
32	3780194	60	$42.8 \pm 0.4$	almost no dendrite formation
33	3780196	61	$42.2 \pm 0.6$	occasional dendrites
34	3780197	62	$41.9 \pm 1.2$	occasional dendrites
35	3780199	63	$26.1 \pm 2.1$	front formation
36	3780200	64	$41.6 \pm 1.1$	occasional dendrites

5        These results show migration of silver ions upon conditioning  
for 3 days at 35°C and 80% relative humidity and subsequent

application of a potential of 100 V DC for 20 minutes in the absence of pretreatment (comparative experiments 2 and 3). A comparison of the results with comparative experiments 1 and 2 show that conditioning clearly promoted silver dendrite growth as  
5 observed in actual devices.

Pretreatment with an aqueous solution of sodium tartrate (STAB02) provided limited restraint as shown by the reduced growth of the silver dendrite front. Pretreatment with high concentrations of sodium sulphide (STAB04) appeared to detach the  
10 silver dendrite front from the electrode. Low concentrations of 5-methyl-s-triazolo[1,5-a]pyrimidin-7-ol (STAB05) also restrained silver dendrite growth as evidenced by the break up of the silver dendrite front into clusters of silver dendrites although this was limited to particular zones.

15 All the 5-mercapto-tetrazoles investigated, with the notable exception of unsubstituted 1-phenyl-5-mercapto-tetrazole [STAB01], also exerted at least a limited restraint on the silver dendrite-formation process as could be seen by at least the appearance of a broken front formed by clusters of silver-dendrites. 1-Phenyl-5-  
20 mercapto-tetrazole itself exhibited this behaviour in the presence of the surfactant Antarox™ CO 630, a non-ionic surfactant. However, substantial restraint was only observed with 1-phenyl-mercapto-tetrazole compounds with the phenyl group substituted with at least one electron accepting group such as halide, acylamino- or  
25 amido-groups as shown by the compounds PMT01 to PMT14. Almost complete restraint was observed upon pretreatment with solutions 29, 30, 31, 39, 43, 44, 46, 51, 54 and 60 i.e. with PMT1, PMT05, PMT06, PMT08, PMT09 and PMT12 almost complete restraint was observed at concentrations of 1-phenyl-5-mercapto-tetrazole with  
30 phenyl groups substituted with electron accepting groups of 0.005%: or lower.

Experiments in photovoltaic devices consisting of a poly(ethylene terephthalate) support/silver grid/screen-printed PEDOT-PSS-containing paste/poly([2-methoxy-5-(2'-ethylhexoxy)-p-  
35 phenylene]vinylene):1-(3-methoxycarbonyl)-propyl-1-1-phenyl-(6,6)C<sub>61</sub> layer/aluminium with and without PMT-1 in the silver grid layer gave the results given in Table 12 upon exposure with a halogen lamp:



Table 12:

	V <sub>OC</sub> [mV]	I <sub>SC</sub> [mA/cm <sup>2</sup> ]
without silver grid	830	0.7
silver grid without PMT-1	740	3.8
silver grid with PMT-1	730	5.2

The results in Table 12 show that the presence of a silver grid  
s increased the short circuit current from 0.7 mA/cm<sup>2</sup> to 3.8 mA/cm<sup>2</sup>  
and reduced the open circuit voltage from 830 to 740 V.

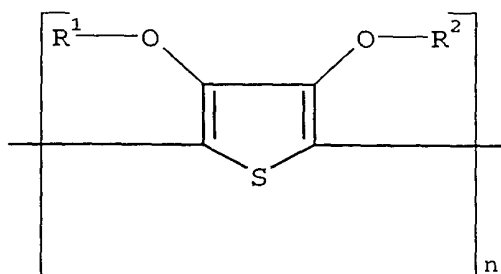
Furthermore, incorporation of PMT-1 in the silver grid layer  
increased the short circuit current (I<sub>SC</sub>) still further to 5.2  
mA/cm<sup>2</sup>.

10

The present invention may include any feature or combination of  
features disclosed herein either implicitly or explicitly or any  
generalisation thereof irrespective of whether it relates to the  
presently claimed invention. In view of the foregoing description  
15 it will be evident to a person skilled in the art that various  
modifications may be made within the scope of the invention.

## CLAIMS

1. A process for preparing a substantially transparent conductive layer configuration on a support, said layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, said process comprising the step of: preparing said second layer by a photographic process.
2. Process according to claim 1, wherein said photographic process comprises the steps of: coating a layer containing silver halide and gelatin with a weight ratio of gelatin to silver halide in the range of 0.05 to 0.3, image-wise exposing said silver halide-containing layer, and developing said exposed silver halide-containing layer to produce said second layer.
3. Process according to claim 1, wherein said photographic process comprises the steps of: coating the support with a layer of a nucleation agent; producing a non-continuous silver layer on said nucleation layer using silver salt diffusion transfer.
4. Process according to claim 3, wherein said nucleation agent is palladium sulphide.
5. Process according to claim 1, wherein said intrinsically conductive polymer contains structural units represented by formula (I):



(I)

wherein n is larger than 1 and each of R<sup>1</sup> and R<sup>2</sup> independently represents hydrogen or an optionally substituted C<sub>1-4</sub> alkyl group or together represent an optionally substituted C<sub>1-4</sub> alkylene group or an optionally substituted cycloalkylene

group, preferably an ethylene group, an optionally alkyl-substituted methylene group, an optionally C<sub>1-12</sub> alkyl- or phenyl-substituted ethylene group, a 1,3-propylene group or a 1,2-cyclohexylene group.

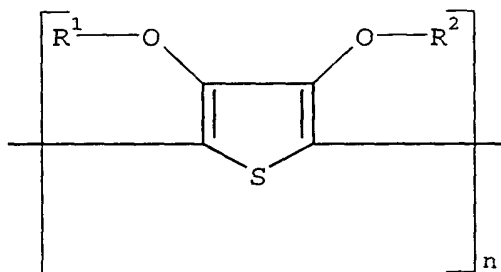
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6. Process according to claim 1, wherein said process further comprises coating said first layer prior to preparing said second layer by a photographic process.
- 10 7. Process according to claim 1, wherein said process further comprises coating said first layer upon said second layer comprising a silver pattern.
8. A layer configuration obtainable by a process for preparing a substantially transparent conductive layer configuration on a support, said layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, said process comprising the step of: preparing said second layer by a photographic process, wherein said layer configuration further contains a 1-phenyl-5-mercapto-tetrazole compound in which the phenyl group is substituted with at least one electron accepting group.
- 15
- 20
- 25 9. A light emitting diode comprising a layer configuration prepared by a process for preparing a substantially transparent conductive layer configuration on a support, said layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, said process comprising the step of: preparing said second layer by a photographic process.
- 30
- 35 10. A photovoltaic device comprising a layer configuration prepared by a process for preparing a substantially transparent conductive layer configuration on a support, said layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, said process comprising the step of: preparing said second layer by a photographic process.
- 40

11. A transistor comprising a layer configuration prepared by a process for preparing a substantially transparent conductive layer configuration on a support, said layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, said process comprising the step of: preparing said second layer by a photographic process.
- 10 12. An electroluminescent device comprising a layer configuration prepared by a process for preparing a substantially transparent conductive layer configuration on a support, said layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer and a second layer consisting of a non-continuous layer of conductive silver, said process comprising the step of: preparing said second layer by a photographic process.

## ABSTRACT

## PROCESS FOR PREPARING A SUBSTANTIALLY TRANSPARENT CONDUCTIVE LAYER CONFIGURATION

- 5 A process for preparing a substantially transparent conductive layer configuration on a support, the layer configuration comprising in any order at least a first layer containing an intrinsically conductive polymer optionally containing structural units represented by formula (I):



(I)

- 10 wherein n is larger than 1 and each of R¹ and R² independently represents hydrogen or an optionally substituted C₁-₄ alkyl group or together represent an optionally substituted C₁-₄ alkylene group or
- 15 an optionally substituted cycloalkylene group, preferably an ethylene group, an optionally alkyl-substituted methylene group, an optionally C₁-₁₂ alkyl- or phenyl-substituted ethylene group, a 1,3-propylene group or a 1,2-cyclohexylene group; and a second layer consisting of a non-continuous layer of conductive silver, the
- 20 process comprising the step of: preparing the second layer by a photographic process; and light emitting diodes, photovoltaic devices, transistors and electroluminescent devices comprising a layer configuration prepared according to this process.

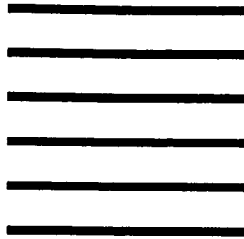
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Figure 1:

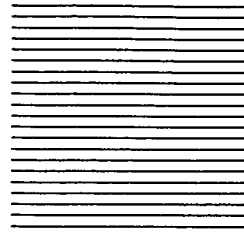


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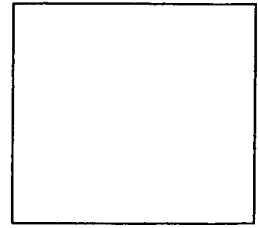
a



b



c



d

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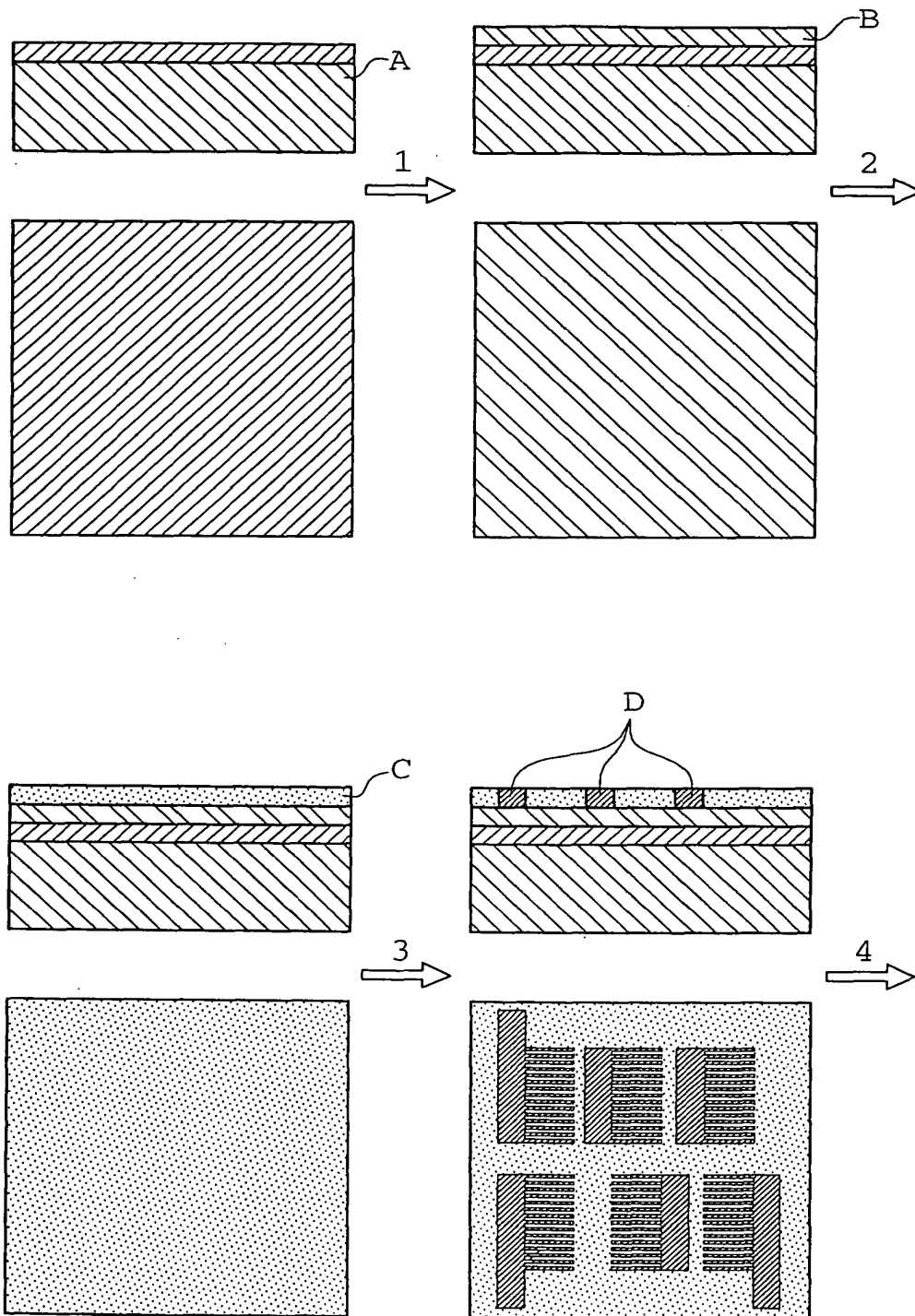


FIG. 2-1

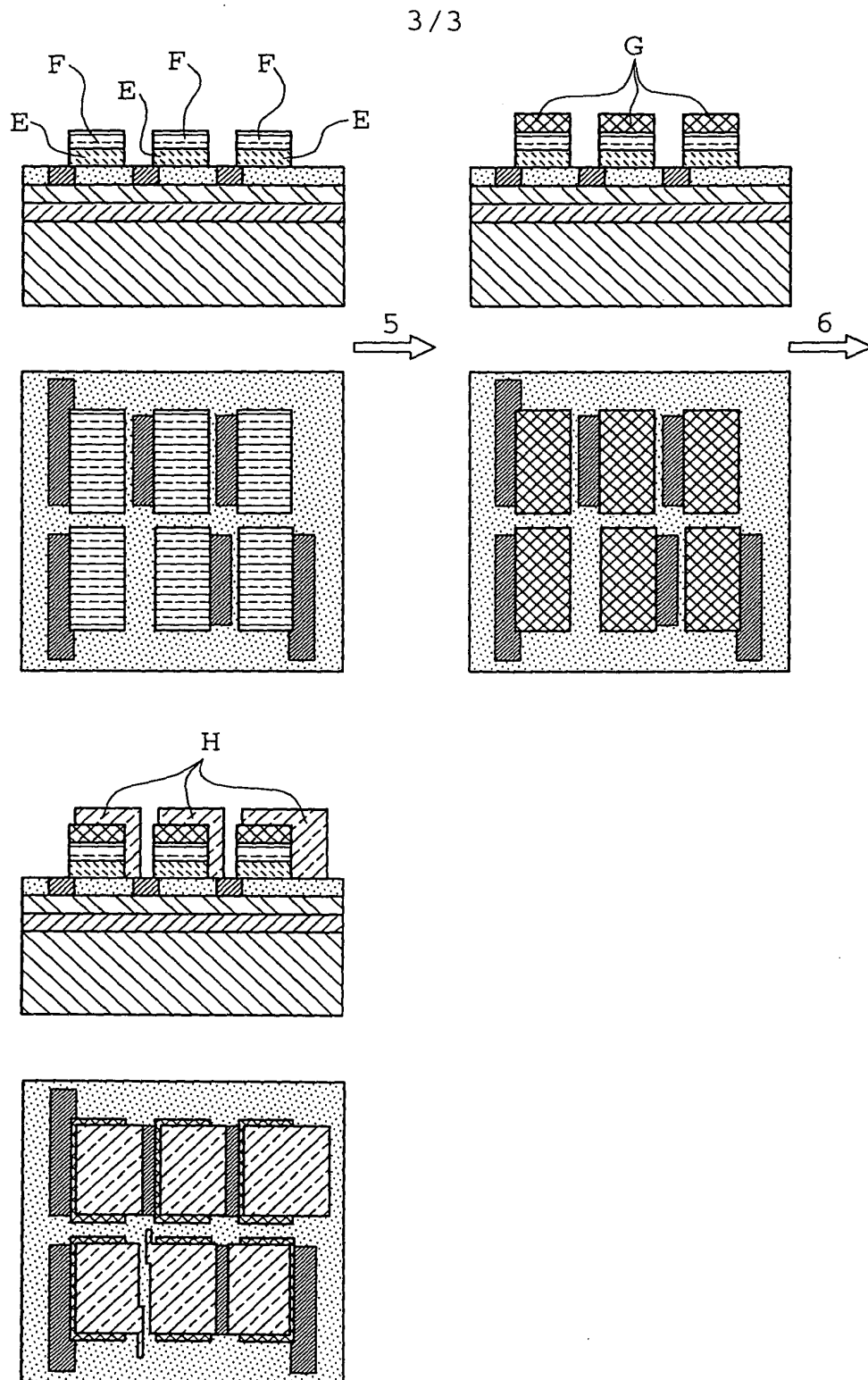


FIG 2-2